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# THE VEGETATION ON BAUXITIC SOILS IN JAMAICA

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*With nine plates*

THE OCCURRENCE of a red-colored, mineral-bearing soil in the Greater Antilles has been recorded in the literature of the area for nearly one hundred fifty years. In the past the principal mineral element has been considered to be iron and its occurrence has been recorded in quantities of commercial significance. It has also long been recognized that these red soils of Jamaica, Cuba, Haiti and the Dominican Republic, generally called "terra rossa" are not particularly fertile for agricultural purposes. The agricultural worker has recognized that terra rossa soils also possess peculiar physical properties relative to erosion, water absorption, slickness to traction and texture. The farmer has acknowledged that special techniques are necessary for even marginal crop production and the botanists have learned of often unusual and endemic plants occurring on these soils.

For Jamaica, the first significant mention of aluminum ores in the red soil appeared in the memoirs of the first official Geological Survey when C. Barrington Brown described a "red ferruginous earth" widely covering a limestone formation as "principally a mixture of iron and alumina" (Sawkins Mem. Geol. Survey (Jam.) 167–8, 1869). While several analyses were made for mineral and agricultural purposes in the succeeding years, it was not until 1939 during the course of a systematic chemical investigation of soil types in Jamaica that the red soils of Jamaica were discovered to contain sufficiently high alumina and low silica percentages to make the soil a satisfactory source of commercial aluminum. Similar deposits are also known from Haiti (Goldich, S. S. & Berquist, H. R., Aluminous lateritic soil of the Republic of Haiti, W.I., U.S. Geol. Sur. Bull. **954–C**: 1948) and from the Dominican Republic (Goldich, S. S. & Berquist, H. R., Aluminous lateritic soil of the Sierra de Bahoruco Area, Dominican Republic, W.I., U.S. Geol. Sur. Bull. **953–C**: 1947). The analytical work of the Agricultural Chemistry division of the Department of Agriculture in Kingston, Jamaica, was directed to a study for improvement of the red, infertile soils of the limestone districts. The first efforts of analysis and improvement were applied at Grove Place in the parish of Manchester and at Bull Savanna in the parish of St. Elizabeth. Similar soils in other parishes then came in for attention and it was in this way that Sir Alfred D'Costa, often incorrectly given credit for the discovery of alumina in Jamaica, secured the analysis of soils on his properties in the Lydford area near Claremont in St. Ann parish. An investigation directed towards commercial exploitation of these potential ore-producing areas was speeded by the war effort in the early 1940's. Post-war surveys later revealed ore in commercial quantities in other areas of Jamaica and between 1949 and the present time three industrial concerns have bought lands for the mining of aluminum-bearing ores. It is now recognized that a major portion of the land surface of the island of Jamaica contains aluminum-rich ore, a sizable percentage of this in commercial quantities, and that bauxite will constitute a major national resource of the island for many years to come. Bauxite and alumina together currently represent the second largest source of income for the island.

The commercial utility of the infertile "terra rossa" soils, however, does not remove the practical and scientific problems of the agricultural use of these soils, both now and in the future, and the botanical problems concerning the nature of the vegetation which occurs in such areas. In fact, commercial mining, using strip-mining techniques, poses other problems in the reclamation of the land and its proper use in the future. In this regard it is encouraging to note that the aluminum mining companies and the government of Jamaica, with its departments of mining, agriculture and forestry, are attempting a many-sided approach to the problems of adaptation and use of bauxite soils prior to and following mining, as well as independent of the mining processes. The legal position of mining operations in Jamaica is covered by The Bauxite and Alumina Industries (Encouragement) Law, Law 12 of 1950. The problems involved are clearly reflected in the Order made under the Law by the Governor in Executive Council on the 18th of September, 1950. This Order stated in part that "the recognized producer shall at all times maintain or cause to be maintained all lands . . . vested in or occupied by the recognized producer and which immediately before they became so vested or occupied were used for agricultural or pastoral purposes in as efficient a state of agricultural or pastoral productivity as such lands were immediately before they became so vested." The second condition of the order is that "so soon as may be after mining operations are concluded in any particular sector the recognized producer shall (a) restore every acre mined in such sector to the level of agricultural or pastoral productivity of such acre which existed immediately prior to the commencement of the mining thereof: or (b) if the Commissioner of Mines is satisfied that it is not economically practicable to comply with the provisions of sub-paragraph (a) of this paragraph as the Government of Jamaica may elect either (i) clear or reclaim one acre of land which immediately prior to such clearing or reclamation was not used for agricultural or pastoral purposes for each acre mined, in the relevant sector; or (ii) pay to the Government of Jamaica the sum of fifty pounds in respect of each acre so mined."

Thus legally the Government of Jamaica recognizes that arable land surfaces are limited in relation to an increasing population which basically has depended and will continue to depend upon its land for sustenance and profit. The law in the basic paragraph is an attempt to continue in useful condition lands temporarily withdrawn from the use of private citizens or small land-holders. The law recognizes that pastures or arable lands left idle in Jamaica, as elsewhere in the Caribbean, are soon reclaimed by noxious weeds, tenacious shrubs or forest growth, imposing on future owners tedious and expensive labor for land reclamation. The law specifies that once mining operations are concluded lands are to be restored to a level of production equal to that which existed prior to the mining process. A far-sighted law further recognizes that the mining of bauxite, being strip-mining in principle, may alter contours of the land in such a way that returning the area to its original condition relative to vegetation is impractical and the Commissioner of Mines, acting as the Government of Jamaica, may suggest either the reclamation of a comparable area of land in the vicinity or the payment of a fine. The goals of this legislation based on English law are to prevent the progressive development of large areas of waste land similar to the barren areas produced by strip-mining in many sections of the British Isles, as well as in the United States and other lands. The nature of the reclamation process has been left in the hands of the Commissioner of Mines who has worked with the cooperation and advice of specialists of the Departments of Agriculture and Forestry and with representatives of the mining companies. The representatives, individually and collectively, recognize the complexity of the problems involved. Thus there is in effect in Jamaica at the present time an honest effort, unique in the Caribbean and in the general history of strip-mining operations, to consider the problems and adapt the results for mutual benefit and for the present and ultimate well-being of Jamaica and its people.

The problems of revegetating mined-out bauxite areas are not simple. They involve acceptance of the fact that the soils are basically poor from the agricultural point of view and that in Jamaica, as in other heavily populated tropical areas, the lands have not received the attention and proper use deemed ideally desirable. The proper use of "terra rossa" soils has not been fully explored, but is currently receiving study and will necessitate continued study. The existing vegetation of bauxite soils is often unusual in habit, association and composition, as this study will show. Replacement of this vegetation by duplication may be difficult and may involve a series of carefully controlled steps. In fact, exact duplication of the existing vegetation may be undesirable and efforts are being made not only to revegetate the soil surface in mined-out bauxite areas, but to produce on these soils a vegetation of greater potential value than existed previously. In some cases this has meant the replacement of shrub-forest vegetation with pasture lands or the obverse replacement of pasture vegetation with forest trees following mining. Adjustments have to be considered relative to the contours developed during mining operations, for steep-sided pits negate the use of pasture grasses or require fencing, while practices of fill or land movements depend on the economics of such operations as well as the machinery required. The relationship between the mineral content of the soil and the nature and growth of the vegetation upon that soil is admittedly complex, and clearly so in the relationship of these plants to aluminum ions. Thus, there are many problems on which representatives of mining, agronomy, forestry, chemistry and botany must share their knowledge. These are problems which are being worked out in Jamaica.

The authors of this paper, working under the auspices of the Institute of Jamaica, have undertaken a survey of the existing vegetation on bauxite soils in Jamaica. The senior author can call upon field experience in the bauxite areas of Hispaniola for comparison, but recognizes that further work is necessary on that island, as well. We have worked with the cooperation of the Commissioner of Mines and the directors and staff members in the Departments of Agriculture and Forestry. Permission to study at will the vegetation of the lands being mined or planned for mining in the future has been granted by the Reynolds Jamaica Mines and the Kaiser Bauxite Company. Over the past three years we have visited each area of mining operation during various seasons of the year. For comparative purposes, similar studies have been made of the vegetation on limestone outcrops adjacent to the bauxite accumulations. Studies are also under way on areas of bauxite accumulations to be considered for mining in the future.

Our efforts, as will be indicated subsequently in this paper, have been to determine the nature and the composition of the vegetation on known accumulations of aluminum-rich bauxite soils. We have studied and recorded the species of plants found in these areas, as well as the relative abundance of economic and academically significant species. Transects and population counts have been made for significant areas. Data are preserved as herbarium specimens collected at various seasons to insure material in flowering and fruiting conditions. Herbarium specimens, suitably indicated as to origin, are on deposit at the Institute of Jamaica and are available at any time for reference or study. Duplicate collections have been placed in the Herbaria of Harvard University, the British Museum of Natural History and the New York Botanical Garden. Additional specimens are available for other interested botanical organizations.

We wish to acknowledge our appreciation to the many individuals and organizations who have assisted materially in the progress of this study. Their cooperation and interest, their financial and intellectual support have made this study a pleasure to us and of benefit in the study of botany in the West Indies. We mention particularly the assistance we have had from Mr. C. P. deFreitas, Commissioner of Lands and Mines; Mr. B. E. Frayling, Deputy Commissioner of Mines; Mr. J. R. Elliott, Deputy Commissioner of Lands; Mr. J. F. Hart, Mines Officer; Mr. E. J. Gregory, Deputy Director of Agriculture; Dr. R. M. Arnold, Superintendent of Livestock Services; Mr. M. S. Motta, Senior Agricultural Officer; Mr. E. M. Brown, Conservator of Forests; Mr. H. S. Deans, Assistant Conservator of Forests; Mr. William S. Cole, Resident Manager of the Reynolds Jamaica Mines and his staff members, Mr. Alastair A. Keeling, Mr. Charles M. Baker and Mr. W. R. McDaniels; Mr. Donald C. Tretzel, Works Manager of the Kaiser Bauxite Company and his staff members, Mr. F. Miles, Mr. W. F. Jones and Mr. E. L. Mais; and finally to Mr. C. Bernard Lewis, Director of the Institute of Jamaica and Mr. Ronald P. Bengry of the Institute staff.

## THE VEGETATION OF THE BAUXITE SOILS AND ADJACENT AREAS

### Location of the Deposits

The survey conducted by the Geological Survey Department has been admirably summarized by Dr. V. A. Zans, senior geologist of the Geological Survey of Jamaica in a publication "Bauxite Resources of Jamaica and Their Development" (London 1954). Mr. Zans points out that through the efforts of the members of the Geological Survey and the geologists of the interested companies, commercial deposits of bauxite ore have been found in the parishes of Manchester, St. Elizabeth, St. Ann and Trelawny. Similar workable deposits are found in the parishes of St. Catherine, Clarendon, St. James and Portland. The other parishes either lack bauxite deposits completely or have only small accumulations of no commercial value. Currently, however, mining operations are limited to three areas in Jamaica. The Reynolds Jamaica Mines are operating on lands in St. Ann parish near Lydford Post Office. The Kaiser Bauxite Company operates areas of bauxitic soils in St. Elizabeth below Spur Tree Hill and south of the crossroads known as Gutters. These are the areas which have received our attention because of the diverse vegetation types represented and the different ecological conditions prevalent in the two areas. A third area of commercial operation is near Shooters Hill in the parish of Manchester, where the Alumina Jamaica Ltd. mines a more limited area similar in aspect to that operated by the Kaiser Company. We have given little attention to this area.

## THE REYNOLDS AREA IN ST. ANN

The lands currently being mined by Reynolds Jamaica Mines are located chiefly among rocky wooded hills southeast of Lydford Post Office in the parish of St. Ann. The ore bodies occur primarily on a plateau in pocket-shaped hollows which range in elevation from 1100 to 1300 feet above sea level (PLATE I, FIG. 1). The surrounding limestone hills are heavily wooded with a rich array of hardwood tree species, an abundance of shrubs, numerous ferns and orchids occurring chiefly as epiphytes on trees on the limestone outcrops and a large number of weedy species of pantropical or Pan-Caribbean distribution occurring on lands once in agricultural or pastoral use.

This area north of Moneague has long been an area of extensive plantations and estates, the names of which, in use today, go back over one hundred fifty years. Patrick Browne's map associated with his "Natural and Civil History of Jamaica" showns no named properties in the Moneague area in 1749 and Hans Sloane ("Voyage to . . . Jamaica" Vol. 1, 1707) mentions only the Moneague Savanna as a feature of the road or tract over Mt. Diablo to St. Ann's Bay. Edward Long in the History of Jamaica published in 1774 (Vol. 2, page 90) describing St. Ann parish avers that "the hills contain very few sugar works. The mould here is extremely superficial; and underneath lies a deep vein of a white marle, or hard chalk. The pimento loves this kind of soil; and vast woods of it overspread the hills to a great distance from the coast. Behind this range of hills and mountains the land is diversified with open, level savannahs, environed by rocky eminences, or with little cock-pits. The soil of the latter is cultivated successfully with guiney-grass. The savannahs are covered with fern, and applied to no use. The road by Monte Diablo, in Sixteen mile-walk, leads into it on the south-east part, and is a mere avenue cut through the woods, there not being more than four or five settlements on the whole road. About five miles from Monte Diablo is the Rio Hoja, which, running about a mile and a half from its first spring, discharges itself into a large lake of immense depth." "The district of the parish intersected by these three avenues (Mt. Diablo, Pedro, Cave Valley roads) comprehends near one hundred and eighty thousand acres, as yet unsettled. In so vast a space, there must needs be a very great variety of soil, and numberless spots of very fine cultivated land. But, exclusive of a few fern savannahs, the whole of it is in its primitive forest, full of large cedar (*Cedrela*), mahogany and other valuable timber trees. The soil, over which the roads pass, is in general a reddish fat clay, intermixed with mould, or a black-shell mould."

Between Long's report of 1774 and 1811, when the first issue of "The New Jamaica Almanac and Register" to contain names of properties was published, the area attracted settlers and by 1810 such estates as Albion, Phoenix Park, Bellmont, Ramble, Grier Park and Crescent Park were evidently well established. Bel(l)mont and Crescent Park, two estate areas currently being mined for bauxite, were reported to have 51 and 99 slaves and 124 and 411 head of stock (including cattle), respectively. These lands have remained in large estates and in the hands of relatively few owners during the last century, and the land has been devoted to the raising of cattle with a few side exploits noted. The mention by Sloane and Long of savannahs and fern areas describes well the current situation with the limited fertile soils occurring as pastures and the shallower soils broken by small outcrops of limestone supporting the areas of fern (*Nephrolepis*). The wooded areas could not be regarded as of comparable productivity today, for while pimento is of scattered occurrence, cedar and mahogany have to a large extent been eliminated. Little information is available whether the depletion of these once richer forested areas came about through lumbering for purposes of construction, fuel for sugar mills closer to the coasts, or by generation after generation of slash cutting for fuel and buildings by residents of the area. All three probably played a role and the shallow soils, underlain by marl, controlled replacement forest growth on the flat lands as the blocks of limestone in the "rocky eminences" limited forest replacement on the hilltops.

A few attempts at diversified crop agriculture have been attempted in the bauxite areas of St. Ann as indicated by the few pimento groves and casual plantings existing as remnant trees of cola, citrus, jak fruit, coffee and cocoa.

The area being mined by Reynolds in St. Ann parish today consists of numerous small glades or depressions partially filled with bauxite soils and low-elevation hills of loose limestone blocks of varying sizes. In recent years the flat lands have been devoted to pastures for cattle raising (PLATE V, FIG. 1). The limits of these areas are clearly defined in the vegetation, for the pastures stop at the rocky outcrop and the forests do not occur on the deeper soils. The margin of these two vegetation types is marked by shrub growth, in part natural and in part created by the convenience of the area for fuel wood cutting. Often these areas are covered with extremely dense stands of fern (*Nephrolepis biserrata*) creating a tangle difficult to penetrate. We have been unable to find an area of deeper soil supporting a forest. We wonder if such areas ever did exist or whether the deeper bauxite soils have always had a savannah vegetation.

## The Environment

Vegetation can be interpreted in terms of soil types and climatic conditions as well as the plants which comprise it. Asprey and Robbins in their recent paper on the Vegetation of Jamaica (Ecological Monographs 23: 359–412. 1953) accept a method of vegetation classification which they state is largely one of convenience, recognizing both environment and species composition. Without discussing the vegetation of terra rossa soils specifically, they refer to them as "residual" soils "developed from weathering of hard white limestone through solutions and being typically coarse and porous in nature." They report that "although under conditions of poor drainage degraded forms of these bauxitic soils occur, they are usually much leached, acid, well oxidized and dehydrated. The red color is due to ferric oxide and their depth over the limestone plateaus varies greatly. There is no distinctive profile, but the surface has a high content of organic matter on which the agricultural value of the land depends." These observations, in our minds, do not appear to apply well to the pasturelands in St. Ann which are subtended by bauxite in commercial quantity. Profiles dug through these areas show very slight penetration of the root systems and relatively little organic content. The root systems of herbaceous plants and woody shrubs rarely penetrate more than eight inches and rarely do tree roots go deeper than two feet. The response of the vegetation to programs of soil improvement indicate natural low nutritional values for plant growth. The soil seems to be a definite limiting factor in the development of better pasture areas or for the growth of forest trees. A soil analysis is available for the areas in St. Ann now being mined but none has been made for the mine area in St. Elizabeth. Samples of surface soil taken no deeper than six inches showed the following analysis which indicates the low level of essential elements:

| | |
|---|---|
| pH | 6.1 |
| Organic matter | 7.68 % |
| Phosphorous | 0.019 — 0.036% |
| Nitrogen | 0.48 — 0.53 % |
| Potassium | 0.07 — 0.14 % |
| Calcium | 0.14 % |
| Iron | 0.84 — 1.63 % |

The soil proved relatively rich in minor trace elements with no conspicuous deficiency noted.

The climatic factors are less restricting. Temperature records for the vicinity of Crescent Park and Lydford Post Office near the mines indicate a mild, even climate with a cloud cover on the hottest of days which aids in reducing transpiration and water loss. Rainfall in the Crescent Park area is favorable, being 66.2 inches per year with peaks in May and in October and November and distributed as follows:

| | | | |
|---|---|---|---|
| January | 3.9 | July | 2.7 |
| February | 3.6 | August | 5.1 |
| March | 4.1 | September | 4.9 |
| April | 4.2 | October | 8.8 |
| May | 9.9 | November | 10.2 |
| June | 3.3 | December | 5.5 |

Accepting the basic figure of four inches of rainfall per month as the minimum figure for optimum plant growth in the West Indies, the Crescent Park area had only four deficient months, distributed in pairs; January–February and June–July, and eight months over the minimum. These eight months are favorably distributed in growing periods of three and five consecutive months.

## The Pastures

The pastures in the area of mining operations in St. Ann are relatively low grade. Without improvement, the average of these would currently support only one head of cattle for every five or six pasture acres. An examination of many of these pr or to the mining operation revealed incipient invasion of woody shrubs and vines which could be kept under control only by constant effort (PLATE V, FIG. 1.) The forage plants were few in number and the unpalatable and therefore untouched grasses and herbs were numerous, if not dominant. The following list represents a fair sample of plants typical of pasture areas in the St. Ann area on bauxite soils prior to mining:

*Andropogon glomeratus*
*Borreria laevis*
*Borreria verticillata*
*Cardiospermum grandiflorum*
*Cassia ligustrina*
*Cassia occidentalis*
*Cassia uniflora*
*Centrosema virginianum*
*Cissampelos pareira*
*Crotalaria incana*
*Desmodium axillare var. acutifolium*
*Desmodium canum*
*Dichromena ciliata*
*Drymaria cordata*
*Eleusine indica*
*Euphorbia heterophylla*
*Euphorbia hirta*
*Euphorbia hyssopifolia*
*Hydrocotyle asiatica*
*Mimosa pudica*
*Nephrolepis biserrata*
*Nephrolepis exaltata*
*Paspalum blodgettii*
*Paspalum conjugatum*
*Paspalum notatum*
*Paspalum paniculatum*
*Passiflora foetida var. hispida*
*Passiflora suberosa*
*Physalis pubescens*
*Phaseolus lathyroides*
*Polygala paniculata*
*Priva lappulacea*
*Pteris longifolia*
*Rubus jamaicensis*
*Setaria geniculata*
*Solanum nigrum*
*Stenotaphrum secundatum*
*Trimezia martinicensis*

The following herbaceous invaders of over-grazed pastures in the St. Ann area which are to be distinguished from the noxious young shrubs capable of dominating pasture areas if untended. Of this list, *Ipomoea cathartica, I. tiliacea, Cissus sicyoides, C. microcarpa* and *Urechites lutea* are vines which become locally dominant through their habit of climbing over the forage grasses present. *Indigofera suffruticosa, Solanum mammosum, S. stellatum, S. torvum, S. verbascifolium, Rhytidophyllum tomentosum* and *Hyptis capitata* become stout plants dominant by size.

*Ambrosia paniculata*
*Asclepias curassavica*
*Asclepias nivea*
*Bidens pilosa*
*Capsicum baccatum*
*Cissus microcarpa*
*Cissus sicyoides*
*Elephantopus mollis*
*Emilia sagittata*
*Emilia sonchifolia*
*Eryngium foetidum*
*Hyptis capitata*
*Indigofera suffruticosa*
*Ipomoea cathartica*
*Ipomoea tiliacea*
*Lobelia viridiflora*
*Mikania micrantha*
*Pavonia spinifex*
*Phyla nodiflora*
*Rhytidophyllum tomentosum*
*Salvia micrantha*
*Sida rhombifolia*
*Sida urens*
*Stachytarpheta jamaicensis*
*Thunbergia alata*
*Triumfetta hispida*
*Triumfetta lappula*
*Urechites lutea*
*Urena lobata*
*Verbesina alata*
*Wedelia gracilis*

Untended pastures are invaded by seedlings of woody shrubs which develop extensively, shading or crowding out more desirable plants.

*Casearia guianensis*
*Chrysophyllum cainito*
*Citharexylum spinosum*
*Cordia globosa*
*Eugenia axillaris*
*Eupatorium odoratum*

*Eupatorium villosum*
*Lantana camara*
*Lantana trifolia*
*Petitia domingensis*
*Psidium guajava*
*Psychotria nervosa*
*Psychotria pedunculata*
*Psychotria pubescens*
*Tournefortia hirsutissima*

The stout woody vine *Tournefortia hirsutissima* reaches extreme lengths in pasture areas and its presence becomes a factor in limiting the pasture available to cattle and humans.

Programs of pasture improvement are under way on properties managed by the Reynolds Jamaica Mines. These programs include controlled grazing, the applications of natural and chemical fertilizers, weed control and reseeding. Such work is being conducted on areas planned for eventual mining, as well as on lands which lack sufficient ore bodies for commercial operation. The development and improvement of these pastures has achieved significant results in the few years of operation, allowing the grazing of cattle in larger numbers. Such a program certainly exceeds the spirit as well as the letter of the mining laws.

## The Wooded Lands

The forest vegetation in St. Ann on lands operated by the Reynolds Jamaica Mines occurs on small limestone hills, outcrops of limestone rock and on the face of a small escarpment. (PLATE I, FIG. 1.) Asprey and Robbins' classification of "lowland type on limestone" would apply to the forests we have observed. As we have indicated, we have been unable to locate any forests on deep deposits of soil, although historical records indicate such forests might have occurred and subsequently been cleared of the trees. All the forests we have observed have been on limestone rock and have possessed only slight accumulations of soil. All have been cut over or severely culled and show the effects of human activity as well as that of nature's ravages of wind, especially hurricane damages, and time. The original forests in these areas must have been a rich mesophytic forest in which such trees as *Terminalia latifolia*, *Dipholis nigra*, *Ceiba pentandra*, *Cedrela odorata*, *Coccoloba swartzii* and *C. plumieri*, as well as other woody genera, occurred. *Swietenia* has not been seen as a natural component of these forests, although Long referred to the abundance of these plants in 1774. Likewise *Pimenta dioica* appears today to be residual plantation trees or occasional spontaneous plants from seed dispersal rather than a component of the mature forest. The forested areas studied are largely open, with relatively little herbaceous growth within the forest. Shrubs and herbs dominate the forest edges near the end of the limestone outcrop. Vines are infrequent except where fellings occurred and newer trees are developing. Epiphytes in abundance, including orchids, bromeliads and ferns reflect the ample rainfall. The dominant forest trees and those reaching the largest size are the following:

*Adenanthera pavonina*
*Alchornea latifolia*
*Andira inermis*
*Casasia piricarpa*
*Cedrela odorata*
*Ceiba pentandra*
*Celtis swartzii*
*Coccoloba longifolia*
*Coccoloba plumieri*
*Coccoloba swartzii*
*Colubrina ferruginosa*
*Cupania glabra*
*Dendropanax arboreum*
*Dipholis nigra*
*Dipholis salicifolia*
*Esenbeckia pentaphylla*
*Ficus harrisii*
*Ficus ochroleuca*
*Ficus wilsoni*
*Guarea glabra*
*Hyperbaena laurifolia*
*Nectandra antillana*
*Nectandra patens*
*Ocotea staminea*
*Oreopanax capitatum*
*Peltophorum brasiliense*
*Petitia domingensis*
*Pimenta dioica*
*Pithecellobium arboreum*
*Pouteria multiflora*
*Simaruba glauca*
*Sloanea jamaicensis*
*Terminalia latifolia*
*Tetrazygia hispida*
*Tetrazygia pallens*
*Torrubia fragrans*
*Wallenia laurifolia*
*Xylopia muricata*
*Zanthoxylum elephantiasis*
*Zanthoxylum martinicense*
*Zizyphus chloroxylon*

To the casual visitors to the forests of St. Ann the dominant plant of the lower stories in the forests may appear to be *Acidoton urens*, known locally as the "cowitch" or "scratch-bush." This plant possesses stinging hairs on most of the younger portions of the stems, on the leaves, flowers and fruits, and causes painful irritation when encountered. Equally abundant are the numerous species of *Psychotria* and *Salpixantha coccinea*. Other woody plants of small stature as well as diameters of less than commercial significance than the dominant trees are:

*Allophylus cominia*
*Bauhinia divaricata*
*Calyptranthes chytraculia*
*Capparis cynophallophora*
*Casearia aculeata*
*Casearia guianensis*
*Casearia odorata*
*Colubrina ferruginosa*
*Daphnopsis americana*
*Drypetes lateriflora*
*Elaeodendron dioecum*
*Erithalis quadrangularis*
*Erythroxylum incrassatum*
*Eugenia disticha*
*Eugenia eperforata*
*Guettarda argentea*
*Hamelia ventricosa*
*Laetia thamnia*
*Maytenus jamaicensis*
*Palicourea domingensis*
*Phyllanthus coxianus*
*Phyllanthus inaequaliflorus*
*Picramnia antidesma*
*Rhamnus sphaerosperma*
*Rheedia sessiliflora*
*Viburnum villosum*
*Xylosma fawcettii*

To determine the size and relative abundance of the forest trees in any given area of forest, we have made transect studies through forest areas selected for the purpose. Some areas were thought to be typical, others showed unusual elements in the flora. Our transects were made by marking off with cord an area 300 feet long and 60 feet wide, representing 18,000 square feet or approximately 41% of an acre. Because of the sharp inclines and the irregular footing in most of the areas studied, cross lines were run to allow counts to be accumulated from smaller areas and trees were marked to prevent chance recounting. The flora is well known to us, yet voucher specimens were collected in cases of doubt.

We recorded the occurrence of all woody species having a trunk diameter of four inches at breast height. Considering the density of the vegetation, even species of known economic potential have little chance of maturing if they are of lesser diameter. However, in several of the transects which follow, these species are indicated in separate listings. Diameters were recorded in categories of 4–6, 7–9, 10–12, 13–15, 15–20 and over 20 inches.

REYNOLDS AREA TRANSECT #1

North slope. Area from lower plain, level of drying kiln up sloping limestone face to level of plateau. Plot 300′ × 60′.

| | Total | 4–6 | 7–9 | 10–12 | 13–15 | 15–20 | Over 20 |
|---|---|---|---|---|---|---|---|
| *Dipholis nigra* | 11 | 1 | 8 | 2 | | | |
| *Simaruba glauca* | 8 | 5 | 1 | 2 | | | |
| *Brunfelsia americana* | 6 | 4 | 2 | | | | |
| *Nectandra antillana* | 6 | 2 | 3 | 1 | | | |
| *Torrubia fragrans* | 6 | 2 | 1 | 1 | 1 | 1 | |
| *Casearia guianensis* | 5 | 5 | | | | | |
| *Celtis swartzii* | 5 | 5 | | | | | |
| *Bunchosia jamaicensis* | 5 | 3 | 1 | | 1 | | |
| *Daphnopsis americana* | 5 | 5 | | | | | |
| *Bauhinia divaricata* | 4 | 3 | 1 | | | | |
| *Zizyphus chloroxylon* | 4 | 2 | 1 | | | 1 | |
| *Zanthoxylum martinicense* | 4 | 3 | | 1 | | | |
| *Casearia sylvestris* | 3 | 1 | | 1 | 1 | | |
| *Sloanea jamaicensis* | 3 | 2 | | | 1 | | |
| *Pithecellobium arboreum* | 3 | | 1 | | 1 | 1 | |
| *Ocotea staminea* | 3 | 2 | | 1 | | | |
| *Cupania glabra* | 3 | 2 | 1 | | | | |
| *Comocladia pinnatifolia* | 2 | 2 | | | | | |
| *Capparis cynophallophora* | 2 | 2 | | | | | |
| *Urera baccifera* | 2 | 1 | 1 | | | | |
| *Coccoloba swartzii* | 2 | 1 | 1 | | | | |
| *Dendropanax arboreum* | 1 | | | | 1 | | |
| *Oreopanax capitatum* | 1 | | | | 1 | | |
| *Andira inermis* | 1 | | | | 1 | | |

The largest of the trees encountered in this transect was 36 inches in diameter at breast height. This was an old and battered specimen of *Pithecellobium arboreum* which would not have produced a log of any value. Three trees with a marketable log over 12 feet long and 2 feet in diameter were found, two of *Torrubia fragrans* and one of *Pithecellobium arboreum*.

The explanation for the greater number of useful trees and trees of larger size and greater frequency in this continuation of TRANSECT #1 can be found in the nature of the rocky substratum onto which TRANSECT #2 extended. This limestone hill consisted of large, irregular, loose blocks of stone. Climbing through the area of steep slopes necessitated the use of two hands. Lumbering in such an area, while not impossible, would be more difficult than cutting trees in the area of TRANSECT #1 where the logs would be dragged to an opening and a roadway with much greater ease.

REYNOLDS AREA TRANSECT #2

A continuation of TRANSECT #1 from the level of mining operation on the plateau to the top of the closest adjacent limestone hill. Plot 150′ × 60′.

| | Total | 4–6 | 7–9 | 10–12 | 13–15 | 15–20 | Over 20 |
|---|---|---|---|---|---|---|---|
| *Nectandra antillana* | 30 | 17 | 9 | 4 | | | |
| *Pouteria multiflora* | 19 | 9 | 5 | 4 | 1 | | |
| *Torrubia fragrans* | 14 | 2 | 2 | 8 | | | 2 |
| *Daphnopsis americana* | 10 | 9 | 1 | | | | |
| *Coccoloba swartzii* | 8 | 6 | 2 | | | | |
| *Alchornea latifolia* | 6 | 5 | 1 | | | | |
| *Cupania glabra* | 5 | 4 | | 1 | | | |
| *Xylopia muricata* | 4 | 3 | 1 | | | | |
| *Wallenia laurifolia* | 4 | 2 | 1 | | | 1 | |
| *Guarea glabra* | 5 | 4 | | 1 | | | |
| *Bauhinia divaricata* | 3 | 3 | | | | | |
| *Pithecellobium arboreum* | 3 | | | 1 | | | 2 |
| *Capparis cynophallophora* | 3 | 3 | | | | | |
| *Guettarda argentea* | 2 | 2 | | | | | |
| *Allophylus cominia* | 2 | 1 | 1 | | | | |
| *Comocladia pinnatifolia* | 1 | 1 | | | | | |
| *Zanthoxylum martinicense* | 1 | 1 | | | | | |
| *Oreopanax capitatum* | 1 | 1 | | | | | |
| *Hyperbaena laurifolia* | 1 | 1 | | | | | |

Another hill in the plateau mine area was selected for a transect study because of the several unique species found in the woods in considerable quantity. One of these trees, *Euphorbia punicea*, was the largest specimen either of us had seen, and apparently the largest on record. The plant has showy bright red bracts 1–1.5 inches long and possesses numerous flower clusters similar to the poinsettia. A specimen of *Euphorbia punicea* nine inches in diameter at breast height and thirty feet high was selected as the corner of a transect of one hundred fifty feet by sixty feet from the top of the hill where the *Euphorbia* grew to the margin of the forest at the lower edges of the hill. This transect showed the following tabular composition:

REYNOLDS AREA TRANSECT #3

Limestone hilltop above mine area on plateau. Hill forest dominated at the peak by specimens of *Euphorbia punicea*. Plot 150′ × 60′.

| | Total | 4–6 | 7–9 | 10–12 | 13–15 | 15–20 | Over 20 |
|---|---|---|---|---|---|---|---|
| *Pouteria multiflora* | 15 | 8 | 2 | 2 | | 2 | 1 |
| *Nectandra antillana* | 9 | 1 | 8 | | | | |
| *Omphalea triandra* | 6 | 4 | 1 | 1 | | | |
| *Alchornea latifolia* | 6 | 1 | 2 | 2 | 1 | | |
| *Torrubia fragrans* | 5 | 1 | 2 | 2 | | | |
| *Casearia guianensis* | 4 | 2 | 1 | 1 | | | |
| *Oreopanax capitatum* | 4 | 1 | 2 | | 1 | | |
| *Comocladia pinnatifolia* | 4 | 4 | | | | | |
| *Exothea paniculata* | 3 | 3 | | | | | |
| *Andira inermis* | 3 | 2 | 1 | | | | |
| *Rhamnus spherosperma* | 3 | 3 | | | | | |
| *Xylopia muricata* | 3 | 3 | | | | | |
| *Euphorbia punicea* | 2 | | 2 | | | | |
| *Coccoloba swartzii* | 2 | 2 | | | | | |
| *Pithecellobium arboreum* | 2 | | | 2 | | | |
| *Dipholis nigra* | 2 | 1 | | 1 | | | |
| *Cupania glabra* | 2 | 1 | | 1 | | | |
| *Zanthoxylum martinicense* | 1 | | 1 | | | | |
| *Capparis cynophallophora* | 1 | 1 | | | | | |
| *Terminalia latifolia* | 1 | | | | 1 | | |
| *Bauhinia divaricata* | 1 | 1 | | | | | |
| *Daphnopsis americana* | 1 | 1 | | | | | |
| *Zizyphus chloroxylon* | 1 | 1 | | | | | |

The "different" appearance of the forest vegetation on this hilltop was supported by the composition study of the transect above. This was accentuated when consideration was given to the shrubby growth and trees having a diameter of less than four inches.

The two hilltops represented in TRANSECTS #2 and #3 were small and the hills more or less conical in shape. Another hilltop in the same area had essentially the same degree of slope to the hilltop but the top was flat and of several acres in extent. This hill drew our closer attention because of the current and relic cultivation which had taken place on its slopes. The steep limestone slope had been cut and burned and crops of *Colocasia*, *Manihot*, *Musa* and *Cajanus* were under cultivation in some areas. Other areas once cultivated had grown up in a dense stand of *Solanum*, *Bocconia* and *Lantana* under trees of *Cecropia*. It appeared to be only a matter of time before cultivation practices would remove the woody vegetation on this hilltop.

The vegetation in this forest was largely undisturbed in the area of the transect. It was dominated, however, by the four very large trees with spreading and dense crowns. One of these, *Oreopanax capitatum*, had a diameter of thirty-six inches at breast height and a trunk extending approximately sixty feet to the first branch. The large specimen of *Pithocellobium arboreum*, with a diameter of twenty-six inches, covered a ground radius of approximately seventy feet and the forest floor was covered with myriad seedlings. A specimen of *Dipholis salicifolia* was a matriarch of the hilltop with a large spreading crown and dense foliage. Seedlings of this aged tree dominated the undergrowth throughout the transect area.

REYNOLDS AREA TRANSECT #4

Flat top of limestone hill above stand of *Cecropia palmata*. Plot 150′ × 60′.

| | Total | 4–6 | 7–9 | 10–12 | 13–15 | 15–20 | Over 20 |
|---|---|---|---|---|---|---|---|
| *Nectandra antillana* | 14 | 5 | 3 | 5 | 1 | | |
| *Dipholis salicifolia* | 11 | 5 | 3 | | 1 | 1 | 1 |
| *Alchornea latifolia* | 11 | 4 | 3 | | 2 | 1 | 1 |
| *Torrubia fragrans* | 9 | | | 7 | | 2 | |
| *Oreopanax capitatum* | 8 | 1 | 1 | 4 | | 1 | 1 |
| *Capparis cynophallophora* | 6 | 4 | 2 | | | | |
| *Pouteria multiflora* | 6 | 3 | | | 2 | 1 | |
| *Wallenia laurifolia* | 6 | 3 | 2 | 1 | | | |
| *Dipholis nigra* | 6 | 1 | 4 | | 1 | | |
| *Coccoloba swartzii* | 4 | 4 | | | | | |
| *Comocladia pinnatifolia* | 4 | 4 | | | | | |
| *Pithecellobium arboreum* | 3 | | | 2 | | | 1 |
| *Zizyphus chloroxylon* | 3 | 3 | | | | | |
| *Terminalia latifolia* | 3 | | 2 | | | 1 | |
| *Omphalea triandra* | 2 | | 1 | | 1 | | |
| *Thrinax* jamaicensis | 1 | 1 | | | | | |
| *Cecropia peltata* | 1 | 1 | | | | | |

The density of young plants under the canopy of the forest trees recorded in the transect varied from the exposed margin to the interior. Variation was also seen relative to the exposure of the slope. A small quadrat twelve feet square was selected and studied in several of these transects and the number and height of the smaller woody plants recorded.

QUADRAT #1 was located in the margin of the forest and the open grassy pasture of the woods reported in TRANSECT #1. This transect contained seventy-one woody plants from one foot tall to over fifteen feet in height, but none of them exceeded two inches in diameter at breast height. Ten genera and species were found as recorded on the next page.

A second quadrat in a comparable area but with a southern exposure had a different composition with thirty-one species represented by sixty-eight individuals in an area twelve feet square. The plants encountered in this quadrat are recorded on the following page.

QUADRAT #1

Upper edge of TRANSECT #2. Western exposure. Plot 10′ × 12′.

| | Total | 1–3′ | 3–7′ | 7–15′ | Over 15′ |
|---|---|---|---|---|---|
| *Acidoton urens* | 19 | 2 | | 3 | 14 |
| *Piper jamaicense* | 10 | 1 | 1 | 8 | |
| *Malvaviscus arboreus* | 7 | | | 3 | 4 |
| *Capparis cynophyllophora* | 7 | 1 | 2 | 4 | |
| *Nectandra patens* | 7 | | 4 | 3 | |
| *Guettarda argentea* | 6 | | | 4 | 2 |
| *Comocladia pinnatifolia* | 5 | 1 | | | 4 |
| *Coccoloba swartzii* | 5 | | | 5 | |
| *Rhytidophyllum tomentosum* | 3 | | 2 | 1 | |
| *Bauhinia divaricata* | 2 | | | 2 | |
| Total | 71 | 5 | 9 | 33 | 24 |

In addition, a small portion of this quadrat contained a colony of *Polypodium polypodioides* growing on a rock and rotted log. The number of individual plants in this colony were too numerous to estimate.

QUADRAT #4

| | | | |
|---|---|---|---|
| *Nectandra antillana* | 20 | *Capparis cynophyllophora* | 1 |
| *Guzmania monostachya* | 13 | *Pouteria multiflora* | 1 |
| *Casearia guianensis* | 10 | *Piscidia piscipula* | 1 |
| *Cereus* sp. | 12 | *Zizyphus chloroxylon* | 1 |
| *Polypodium plumula* | 8 | *Clusia* sp. | 1 |
| *Eugenia* sp. | 6 | *Dendropanax arboreum* | 1 |
| *Hohenbergia* sp. | 4 | *Ocotea floribunda* | 1 |
| *Tillandsia valenzuelana* | 3 | *Zanthoxylum martinicense* | 1 |
| *Cupania glabra* | 3 | *Ipomoea* sp. | 1 |
| *Campyloneuron phyllitidis* | 3 | *Cedrela odorata* | 1 |
| *Comocladia pinnatifolia* | 2 | *Rhipsalis cassytha* | 1 |
| *Lonchocarpus* sp. | 2 | *Anthurium grandifolium* | 1 |
| *Chiococca parvifolia* | 2 | *Campylocentron* sp. | 1 |
| *Coccoloba swartzii* | 2 | *Peperomia amplexicaulis* | 1 |
| *Calyptranthes chytraculia* | 2 | *Tillandsia tenuifolia* | 1 |

The relationship between the sizable plants usually counted for a transect and the number of smaller plants of no economic, i.e., timber, value is frequently not taken into consideration. The development of any seedling into a mature plant is determined in nature, in Jamaican woodlands at least, by a number of factors including the presence or absence of competitors; the number of vines which may cause contortion or strangulation; the nature of the rock substratum on which the seedling obtains its start; the number of larger trees which may die or fall, limiting the growth of the younger plants, and the activity of termites in the area, to mention only a few.

One wooded area near the head of the conveyor belt at the Reynolds Jamaica Mines represented a mature forest area which, previous to mining operations, had been isolated by its location away from roads and bounded by rather difficult rocky slopes. During the course of our trips to this area this forest, now readily available to man on foot or in a car, has been attacked by machete and hoe. This forest proved to have a slightly different composition in its mature trees from the forests encountered and recorded in the transects just cited. The specimens were tabulated as follows:

Reynolds Area Transect #5

Northern exposure, summit of limestone hill. Plot 300′ × 60′.

| | Total | 4–6 | 7–9 | 10–12 | 13–15 | 15–20 | Over 20 |
|---|---|---|---|---|---|---|---|
| *Nectandra antillana* | 7 | 3 | 1 | 3 | | | |
| *Rhamnus sphaerosperma* | 7 | 4 | 2 | 1 | | | |
| *Ocotea floribunda* | 6 | 1 | 5 | | | | |
| *Torrubia fragrans* | 6 | 1 | | 3 | | 1 | 1 |
| *Cupania glabra* | 4 | 2 | 1 | 1 | | | |
| *Guarea glabra* | 4 | | 3 | | 1 | | |
| *Allophylus cominia* | 4 | 3 | 1 | | | | |
| *Andira inermis* | 4 | 2 | | 2 | | | |
| *Daphnopsis americana* | 4 | 3 | 1 | | | | |
| *Zanthoxylum martinicense* | 3 | | 1 | | 1 | | 1 |
| *Alchornea latifolia* | 3 | | 2 | | 1 | | |
| *Casearia guianensis* | 2 | | 1 | 1 | | | |
| *Oreopanax capitatum* | 2 | | | 1 | | | 1 |
| *Annona jamaicensis* | 1 | | | | 1 | | |
| *Phyllanthus coxianus* | 1 | 1 | | | | | |

With this tabulation complete, a line was then placed through the center of the transect and all plants within a distance of 1.5 feet on either side of the line were recorded. A total of 451 plants, representing 40 genera and 45 species, were counted. Because of the smaller size of the plants in this sample, only four of the 451 plants had appeared in the transect tabulation, although no conscious effort to avoid them was made in laying out the line.

The great diversity of the vegetation is, of course, one of the attractions which the vegetation of Jamaica and the Caribbean area in general have for the botanist. The diversity in genera and species is clearly indicated in the transects and quadrats compiled for the forested areas in the parish of St. Ann. The variations between hilltops, not only in aspect but in actual composition, are shown. Species and genera present, often dominant in one mixed forest on one hilltop, will be fewer in number or absent on the adjacent hill.

From an economic point of view, these are not profitable forests. The plants which make up the wooded areas are small in size and few in number. Whether these areas ever contained what today would be considered marketable timber trees is a matter of conjecture. Even if Long's description of 1774 is accurate for the two species of commercial value which he mentions, *Cedrela* and *Swietenia*, some question must be raised as to whether these species could ever have dominated the area in view of the current mixed stands present. The trees which comprise the present forests are not important timber trees. Only a few, a dozen at most, of the species encountered in these areas are important trees and the majority of these are significant from the standpoint of cabinet woods alone. It is possible that in the past one hundred fifty years the marketable trees have been removed from the area either for lumber or for fuel. If that were so, one would expect a few gnarled old giants which, lacking good form or proximity to access roads, would have persisted. Such trees are rarely found and the "forest giants" are almost without exception trees of little commercial value and for that reason alone remain uncut.

QUADRAT #5

Top of hill near loading pit for conveyor belt. Plot 300′ × 3′.

| | | | |
|---|---|---|---|
| *Piper jamaicensis* | 51 | *Cupania glabra* | 6 |
| *Acidoton urens* | 45 | *Coccoloba longifolia* | 5 |
| *Pilea crassifolia* | 38 | *Daphnopsis americana* | 5 |
| *Eugenia disticha* | 35 | *Blakea trinervia* | 5 |
| *Rhytidophyllum tomentosum* | 27 | *Chiococca parvifolia* | 4 |
| *Psychotria* sp. | 21 | *Hamelia patens* | 4 |
| *Eupatorium macrophyllum* | 21 | *Andira inermis* | 4 |
| *Guettarda argentea* | 18 | *Casearia odorata* | 4 |
| *Eugenia axillaris* | 17 | *Guarea glabra* | 3 |
| *Nectandra antillana* | 15 | *Casearia sylvestris* | 3 |
| *Piper arboreum* | 14 | *Wallenia laurifolia* | 3 |
| *Calyptranthes chytraculia* | 14 | *Paullinia jamaicensis* | 3 |
| *Bauhinia divaricata* | 12 | *Salpixantha coccinea* | 3 |
| *Rhamnus sphaerosperma* | 9 | *Zanthoxylum martinicense* | 3 |
| *Casearia guianensis* | 9 | *Xylosma fawcettii* | 3 |
| *Coccoloba swartzii* | 9 | *Cestrum diurnum* | 3 |
| *Comocladia pinnatifolia* | 7 | *Bunchosia swartziana* | 3 |
| *Eupatorium villosum* | 7 | *Allophylus cominia* | 3 |
| *Torrubia fragrans* | 7 | *Tetrazygia hispida* | 2 |
| *Viburnum villosum* | 7 | *Xylopia muricata* | 2 |
| *Ocotea staminea* | 7 | *Alchornea latifolia* | 2 |
| *Miconia laevigata* | 7 | *Pithecellobium arboreum* | 1 |
| | | *Annona jamaicensis* | 1 |

The question might be raised as to why the trees which we studied in the forests of the St. Ann parish are no larger. Reasons for this lack of size were sought in a careful study of the areas represented by TRANSECTS #1 and #2. Possible answers were numerous. The area of the forest consisted primarily of limestone hills and the hills were composed of large blocks of limestone more or less tumbled in position. Hill areas not of distinct blocks consisted of limestone deeply fissured, often in a checkerboard pattern. This substratum which did not possess an accumulation of soil or humus represented an inferior spot for seed germination or for tree growth. Numerous seedlings encountered appeared to grow only to the extent of the stored food present in the cotyledons. Root development was poor and, with little humus to hold water, it appeared that most of the seedlings died from lack of available moisture, even though the area received an average of sixty-six inches per year. Forest litter, where such occurred, could be exceedingly dry during many of the seasons of our visits.

In the two transect areas studied, only four large trees could be considered as rooting in sufficient soil and that generally accumulated in the fissures of boulders. The vast majority of the trees were rooted on blocks of limestone with the roots extending around and below the blocks, as well as penetrating into the porous limestone. The effect of such a rooting habit was particularly evident in this area which received the effects of the last two major hurricanes in 1944 and 1951. Some of the largest trees were prostrate and rotting and an examination of the bases of these plants revealed that the blocks holding the trees had given way. The roots remained securely fastened to a tilted block of stone. It is apparent that the hurricane felled trees in this area of the Caribbean not by uprooting trees or fracturing trunks but by an indirect factor; i.e., alteration of the substratum.

Another factor in the relationship of tree species persistence to size and age is present in the limestone which, while hard, is eroded by the heavy rainfall in combination with the natural acids produced by decaying vegetative matter. The erosion of these blocks into a type of dog-tooth limestone is all too evident to the botanist who traverses these forests.

The effects of the vines and lianas, alone and in combination with the other effects mentioned here, in such a forest is also a factor in tree growth. Vines were not abundant in the very dense forests, but where openings occurred through natural or man-made causes, the vines appeared to scramble, with the aid of the smaller shrubs and saplings, into the tops of the larger trees. The extent and mass of some of these vines were surprising and a calculation of the weight involved in some of the larger woody vines would be a most imposing sum. Huge woody epiphytes or vines in this area included *Blakea trinervia*, *Clusia* sp., *Ficus* spp., *Solandra grandiflora*, *Rourea paucifoliata*, *Schlegelia parasitica* and *Ipomoea grisebachii*. Lighter weight vines or scrambling plants included *Chiococca parvifolia*, *Vernonia acuminata* and *Vernonia cinerea*, *Eupatorium odoratum*, *Clematis dioica* and *Notoptera hirsuta*. The effects of these plants would be felt through the dead weight involved, the concerted pull of the vines in any wind-induced movement of the forest canopy and in the tension exerted by the vine through its growth in various directions. It seemed obvious, from several trees we felled and others we observed in a contorted fashion, that the death or destruction of one tree entangled in vines would be reflected on the others nearby and their growth pattern altered accordingly. In the younger plants the weight and pull of the young vines often contorted the sapling, removing completely the possibility of normal growth into a desirable timber tree. Strangulation of the host tree by the climbing vines was also apparent in the abnormal growth of the stems being squeezed.

A final effect was due to the activity of wood-eating termites in these forests. Termite tubes and termite nests were present on living and dead trees alike. Apparently any injury to a forest tree producing a break in the stem opened an avenue of attack from termites. Certainly the rapidity with which fallen timbers disappear is a tribute to the appetite and activity of the large termite population. These insects obviously play another role in the rapid destruction and alteration of potential timber trees in the tropics. The contrast is found in the temperate areas away from termite attacks where broken branches or trunk wounds would be healed over by callus tissue. Such self-repair is rarely encountered in the forests of the West Indies.

## THE KAISER AREA IN ST. ELIZABETH

### Location and Environment

The Kaiser Bauxite Company is currently mining bauxite soil in a dry, broad valley in the parish of St. Elizabeth (PLATE VI, FIG. 1 and PLATE VII, FIG. 1.) A view west from the company offices on Spur Tree Hill looking towards the Santa Cruz mountains and Malvern details the mining operation in the valley 1600 feet below. A road south from Gutters to Alligator Pond runs the length of this valley and the headquarters for the present mining operation is at a new location appropriately (but by coincidence) called New Buildings. In many aspects, from the techniques of mining to the vegetation involved, there are contrasts with the area in St. Ann operated by the Reynolds Mines. The same attention and techniques have been applied in our study to the pastures and forests associated with the bauxite deposits, but usually with less comfort. The entire mining area is lower in altitude, being only about 700 feet above sea level. Its location on the south coast of the island places it in the lesser southern rainfall division. The rainfall recorded during the year at New Buildings in contrast to Crescent Park totalled 44.75 inches, with lesser peaks in June and October–November.

The monthly rainfall has been recorded as follows:

| | | | |
|---|---|---|---|
| January | 2.42 | July | 0.72 |
| February | 1.82 | August | 4.80 |
| March | 0.94 | September | 4.23 |
| April | 3.37 | October | 6.35 |
| May | 3.75 | November | 10.31 |
| June | 5.19 | December | 0.85 |

The distribution of rainfall as recorded at New Buildings indicates that seven of the twelve months receive less than the four inches of rain considered necessary for optimum plant growth. Two additional months, August and September, receive only slightly in excess of the minimum. The number of consecutive months receiving above the minimum rainfall is also less in comparison with Crescent Park. These occur in August, September, October and November. The isolated month of June also receives above the minimum rainfall.

The temperatures in the valley also mount to greater heights and the evaporation rate is also high due to the extraordinary number of sunny days.

From the standpoint of climatic factors alone, the vegetation present in the Gutters valley exists under comparatively different conditions. As might be expected, the nature and composition of this vegetation is also different. Unfortunately, soil analyses are not currently available for these soils.

A map published in Patrick Browne's description of Jamaica of 1749 shows a "Pepper" plantation near Gutters and also a road south to Alligator Pond. Sloane apparently makes no mention of this area but Edward Long (The History of Jamaica 2: 185, 1774) reports that "about the foot of Mayday Hills the breadnut trees grow luxuriantly, and afford to the bordering settlements great abundance of nourishing fodder for their flocks." Long (l.c. 189) also refers to the area as "Labour-in-vain savannah" a term he states is "perfectly descriptive of its nature." He further comments that "In these parts there are but few sugar-plantations, though a great number of very fine penns for breeding horned cattle, horses, mules, sheep and goats, as well as poultry of all kinds."

Specific historical evidence for the properties now being mined is lacking. The New Jamaica Almanac citing statistics for the year 1810 apparently fails to list a single property in the immediate area of New Buildings. Plantations to the north toward Santa Cruz and the northwest foothills of the Santa Cruz Mountains supported 1529 and 1447 head of cattle, while plantations nearer by are cited as owning five and ten head of cattle. It seems obvious that high-quality pastures have never existed in the Gutters area.

Within the last few decades a special type of cultivation involving heavy mulching with quantities of guinea grass has developed and permitted the use of the land by small holders for the production of root crops, tobacco, pigeon peas and tomatoes. Large land holdings for the breeding and raising of cattle and other animals have largely disappeared. The lack of certain water supplies has reduced the emphasis on cattle raising with the result that few pasture areas comparable to those of the St. Ann area are to be seen. The lands now operated by the Kaiser Bauxite Company therefore involve fewer areas of pasture and more small crop fields now removed from cultivation.

## The Pastures

A study of the areas to be mined which have been devoted to pastures revealed a very low grade forage present composed of a larger number of grasses than we encountered in St. Ann. A survey of these pastures revealed the following grasses:

| | |
|---|---|
| *Andropogon glomeratus* | *Panicum adspersum* |
| *Andropogon virginicus* | *Paspalum caespitosum* |
| *Axonopus compressus* | *Paspalum fimbriatum* |
| *Cenchrus echinatus* | *Paspalum propinquum* |
| *Cenchrus gracillimus* | *Pennisetum purpureum* |
| *Chloris petraea* | *Setaria geniculata* |
| *Digitaria sanguinalis* | *Sporobolus indicus* |
| *Eleusine indica* | *Trichachne insularis* |

Several of these species unpalatable to cattle had become dominant. While guinea grass, para grass and napier grass have been introduced in some areas and have remained as dominant stands when properly cared for, in adjacent areas they have given way to unpalatable species, reducing the value of the pasture. Weedy herbaceous invaders comprised essentially the same species as reported for pastures in St. Ann. Woody invaders of marginal pastures or pastures which have been neglected appear to grow faster and assume dominant roles much faster in this lowland area. One area under our observation for the years of this study changed so markedly that a quadrat study was made. This area was functional pasture in December, 1953. In January of 1956 (PLATE VI, FIG. 1) the shrubs had become so large and abundant that penetration was difficult and cattle tended to avoid the section. The area studied was located near a stand of logwood and the area selected for quadrat study was a hundred yards from the margin of this thicket. The following woody species were encountered in this effectively abandoned pasture:

QUADRAT #6

Kaiser property near New Buildings — area 101. Plot 40′ × 40′.
The number of individuals of all woody species over 12″ tall are recorded in the table.

| | | | |
|---|---|---|---|
| *Haematoxylon campechianum* | 350 | *Cordia globosa* | 5 |
| *Lantana camara* | 44 | *Urechites lutea* | 4 |
| *Colubrina ferruginosa* | 42 | *Ayenia pusilla* | 3 |
| *Casearia guianensis* | 36 | *Wissadula amplissima* | 2 |
| *Eupatorium odoratum* | 26 | *Hyptis pectinata* | 2 |
| *Waltheria americana* | 23 | *Crescentia cujete* | 2 |
| *Melochia pyramidata* | 19 | *Zanthoxylum martinicensis* | 2 |
| *Triumfetta lappula* | 17 | *Solanum verbascifolium* | 2 |
| *Cordia jamaicensis* | 17 | *Indigofera suffruticosa* | 1 |
| *Croton lucidus* | 16 | *Abutilon crispum* | 1 |
| *Guazuma ulmifolia* | 9 | *Psidium guajava* | 1 |
| *Calliandra portoricensis* | 7 | | |

The number and size of the plants which had invaded this pasture and developed to maturity in a period of two years is indicative of the problems of maintaining high quality pastures in Jamaica. While seedlings were present at the time of our first observation, cattle roamed and grazed in this area freely. Two years later the woody plants, especially the thorny *Haematoxylon,* constituted a real barrier. A total of 631 individuals over 12 inches tall in an area of 1600 square feet of pasture were counted. The largest plants encountered were a specimen of *Haematoxylon* 12 feet tall and 1.5 inches in diameter at the base; plants of *Lantana camara* (also spiny) and *Eupatorium odoratum* seven feet tall; specimens of *Hyptis pectinata* reached seven feet, as did spreading plants of *Solanum verbascifolium.* These latter two species spread prolifically once established in a pasture. The basic forage species of *Paspalum* and *Panicum* had given way to a dominance of *Andropogon* which cattle are reluctant to eat.

The sample represented by the QUADRAT #6 is not an exception to the general invasion and replacement affecting pastures in the valley of Gutters. Maintenance of pastures in this area requires constant care and prudent grazing practices.

The planting practices instituted by the Kaiser Bauxite Company on mined-out pits will be considered later. Within the first few years of operation, however, it appears as though limited pasture areas planted to good forage grasses carefully managed may persist as economical forage lands. (PLATE VII, FIG. 2.)

## The Wooded Lands

The broad, flat valley around New Buildings contains low limestone outcrops rarely 100 feet high which support forests. (PLATE VI, FIG. 1 and PLÂTE VII, FIG. 2.) In general the limestone here is not in loose blocks, but exists as a solid, though checked, outcrop. Humus or soil is scarcely more abundant than in St. Ann, but is thick enough in places to allow tree growth upon the soil layer. The majority of these forests are secondary growth, having been cut continuously and now have few large trees other than specimens of *Bursera simaruba.* We were fortunate to find in one area of the Kaiser property a forest on a limestone outcrop which apparently has been well protected. No evidence of cutting was found on our first visit, although cutting has occurred subsequently. A transect study was made of this area and showed a composition as follows:

TRANSECT #6

Kaiser property, area 101. Forest on low limestone outcrop of 25 feet relief apparently protected and undisturbed. Plot 300′ × 60′.

| | Total | 4–6 | 7–9 | 10–12 | 13–15 | 15–20 | Over 20 |
|---|---|---|---|---|---|---|---|
| *Dipholis salicifolia* | 67 | 20 | 4 | 23 | 8 | 10 | 2 |
| *Ocotea staminea* | 8 | 6 | 1 | 1 | | | |
| *Hyperbaena domingensis* | 6 | 4 | | 2 | | | |
| *Calyptranthes chytraculia* | 5 | 4 | | 1 | | | |
| *Thrinax* sp. | 5 | 5 | | | | | |
| *Casasia longipes* | 4 | 2 | 1 | 1 | | | |
| *Guarea glabra* | 4 | 2 | 1 | 1 | | | |
| *Coccoloba proctori* | 4 | 1 | 1 | | | | 2 |
| *Zanthoxylum insularis* | 4 | 1 | 2 | 1 | | | |
| *Coccoloba swartzii* | 3 | 3 | | | | | |
| *Wallenia laurifolia* | 2 | 2 | | | | | |
| *Omphalea triandra* | 2 | 2 | | | | | |
| *Lonchocarpus domingensis* | 1 | | 1 | | | | |
| *Comocladia pinnatifolia* | 1 | 1 | | | | | |
| *Bursera simaruba* | 1 | | | | | 1 | |
| *Sarcomphalus laurinus* | 1 | | 1 | | | | |
| *Piscidia piscipula* | 1 | | 1 | | | | |
| *Bauhinia divaricata* | 1 | 1 | | | | | |

The largest trees on this limestone forest represent some of the largest of their species known to us to exist in Jamaica. *Coccoloba proctori*, a new species, certainly fits that category but exceeds in two trees (36 and 24 inches in diameter at breast height) the largest specimens of this important timber genus known in the West Indies. The large number of *Dipholis* specimens, known locally as "bullet" would represent a significant forest resource if the pattern of distribution observed in this forest were repeated in the vicinity. Unfortunately this is not true and the occurrence of "bullet" here can only be taken as indication that the species does well in this area and should be considered as one of the species to be replanted on the mined-out pits.

The succession from pasture to forest land in the Gutters area is clearly marked in a number of woodlands. The shrubby growth described above which invades a misused pasture may assume control and is soon dominated by the logwood (*Haematoxylon*) in this dry area (PLATE VI, FIG. 1.) Apparently the only exceptions we have seen to this first step was a thicket of *Leucaena glauca*. In the majority of instances observed, however, the logwood was prevalent. In flat areas with a bauxite base, the logwood remained as the dominant tree and several of the old stands are being exploited today with logs collected for commercial use as a source of dye (PLATE IX, FIG. 1). On limestone, however, the logwood thicket soon becomes host to smaller plants of other tree species. In several logwood thickets we observed the development of specimens of *Nectandra coriacea*, *Wallenia laurifolia*, *Casasia longipes*, *Cupania glabra*, *Piscidia* *piscipula, Metopium brownei, Coccoloba swartzii, Zanthoxylum insularis, Zanthoxylum flavum, Dipholis salicifolia*, and *Diospyros tetrasperma*. In time these simple or broader leafed species assume dominance over the compound leaves of *Haematoxylon* and apparently crowd out the latter. Dead and dying mature trees of logwood are common in limestone-based secondary forest thickets. These secondary forests are more diverse in their composition than the undisturbed forest previously described.

One limestone outcrop now supporting a secondary forest was distinguished as a former old field by the presence of stone walls traversing it. A transect in this area showed the following composition.

TRANSECT #7

Secondary forest on limestone. Kaiser property, area #18. Plot 300′ × 60′.

| | Total | 4–6 | 7–9 | 10–12 | 13–15 | 15–20 |
|---|---|---|---|---|---|---|
| *Metopium brownei* | 31 | 24 | 6 | 1 | | |
| *Bursera simaruba* | 12 | 6 | 5 | 1 | | |
| *Haematoxylon campechianum* | 12 | 11 | | 1 | | |
| *Diospyros tetrasperma* | 10 | 10 | | | | |
| *Lonchocarpus domingensis* | 7 | 7 | | | | |
| *Dipholis salicifolia* | 6 | 6 | | | | |
| *Simaruba glauca* | 5 | 4 | | 1 | | |
| *Tabebuia riparia* | 5 | 3 | | 2 | | |
| *Piscidia piscipula* | 5 | 5 | | | | |
| *Zanthoxylum flavum* | 4 | 4 | | | | |
| *Coccoloba swartzii* | 4 | 4 | | | | |
| *Exothea paniculata* | 3 | 3 | | | | |
| *Clusia* sp. | 3 | 2 | | 1 | | |
| *Gymnanthes lucida* | 2 | 2 | | | | |
| *Allophylus cominia* | 2 | 2 | | | | |
| *Picramnia antidesma* | 1 | 1 | | | | |
| *Krugiodendron ferreum* | 1 | 1 | | | | |
| *Bauhinia divaricata* | 1 | 1 | | | | |

Consideration in the transect was limited to trees having a diameter of four inches or more at breast height. In addition to these established trees, representatives of the following genera and species were found in the same area.

*Acidoton urens*
*Bunchosia swartziana*
*Casearia sylvestris*
*Celtis swartzii*
*Chiococca parvifolia*
*Clusia flava*
*Cordia globosa*
*Cordia jamaicensis*
*Croton linearis*
*Cupania glabra*
*Erythroxylon confusum*
*Eugenia* sp.
*Hamelia chrysantha*
*Phyllanthus nutans*
*Pisonia aculeata*
*Portlandia grandiflora*
*Psychotria myrstiphyllum*
*Schaefferia frutescens*
*Spathelia sorbifolia*
*Tabebuia angustata*
*Thrinax* sp.
*Xylosma* sp.

One limestone outcrop was found supporting a secondary forest which extended into a pasture currently in use. A transect was made of this forest area beginning immediately behind the young shrub and tree area which could be distinguished as the pasture.

TRANSECT #8

Secondary woodland invading current pasture. Area 101 Kaiser property. Plot 300′ × 60′.

| | Total | 4–6 | 7–9 | 10–12 | 13–15 | 15–20 | Over 20 |
|---|---|---|---|---|---|---|---|
| *Dipholis salicifolia* | 14 | 8 | 3 | 2 | | | 1 |
| *Diospyros tetrasperma* | 14 | 10 | 3 | 1 | | | |
| *Bauhinia divaricata* | 12 | 9 | 1 | 2 | | | |
| *Haematoxylon campechianum* | 9 | 8 | | 1 | | | |
| *Coccoloba swartzii* | 9 | 7 | | | 2 | | |
| *Ocotea staminea* | 7 | 6 | | 1 | | | |
| *Gymnanthes lucida* | 6 | 5 | 1 | | | | |
| *Bursera simaruba* | 4 | | 1 | 2 | 1 | | |
| *Amyris elemifera* | 3 | 2 | 1 | | | | |
| *Wallenia laurifolia* | 3 | 3 | | | | | |
| *Simaruba glauca* | 3 | 1 | 1 | | 1 | | |
| *Calyptranthes chytraculia* | 2 | 2 | | | | | |
| *Piscidia piscipula* | 2 | 1 | 1 | | | | |
| *Casasia longipes* | 2 | 1 | | | 1 | | |
| *Picramnia antidesmia* | 2 | 1 | | | 1 | | |
| *Esenbeckia pentaphylla* | 2 | | 1 | | | 1 | |
| *Zanthoxylum flavum* | 2 | 2 | | | | | |
| *Oreopanax capitatum* | 2 | | 1 | 1 | | | |
| *Metopium brownei* | 2 | | | 2 | | | |
| *Exothea paniculata* | 2 | 1 | 1 | | | | |
| *Sarcomphalus laurinus* | 1 | 1 | | | | | |
| *Casearia guianensis* | 1 | 1 | | | | | |
| *Cupania glabra* | 1 | 1 | | | | | |
| *Capparis cynophallophora* | 1 | 1 | | | | | |
| *Coccoloba diversifolia* | 1 | 1 | | | | | |

The dry land forests of the Gutters area are more open in aspect than the forests of St. Ann. In spite of the relative abundance of light reaching the forest floor, herbaceous growth is scanty and consists primarily of a few species of ferns and *Peperomia*. No orchids have been seen in the areas examined. Epiphytes are numerous in local areas, but consist primarily of *Tillandsia recurvata* and *Tillandsia balbisiana*. *Syngonium auritum* occurs on the exposed limestone. The composition of these forests, primary or secondary, consists of a larger number of genera and species than were found in the forests of the wetter areas of St. Ann. The forests likewise appeared to have suffered greater ravages from man by being cut for fuel and building purposes. The economic value of the limestone forests for lumber purposes is low.

A complete listing of the species found on lands to be mined, as invaders of mined-out pits and as occupants of the adjacent limestone outcrops to bauxite deposits is given in the second part of this paper for both the locations in St. Ann and St. Elizabeth.

## THE RELATION OF THE VEGETATION TO ALUMINUM IN THE SOIL

The relationship of the plant to the soil has formed the basis for most agricultural research since man first cultivated plants. From such studies over a period of time has come our knowledge of root growth, structure and function, of mineral relationships to plant metabolism and growth involving major and minor elements, including trace elements and plant tolerances, preferences and responses to mineral elements, whether as deficiencies or in toxic abundance. As a companion study the botanist has often sought in the plant or the soil evidences of controlling factors in mineral-plant relationships. The recognition of plants as indicators of mineral components has attracted research and guided exploration for gold, iron and more recently for uranium. It is not unnatural, then, that we looked for plants as indicators of aluminum concentrations in our study of bauxite soils. The senior author, on previous field trips in Hispaniola, encountered several species of plants which are known only from depressions rich in bauxite and which are currently the site of mining operations. More recent collecting has not shown these plants on other than aluminum-rich soils. Whether such plants should be considered as indicators of aluminum soil or only plants tolerant of aluminum ions in the soil, in contrast to other species, remains to be established. Agricultural research dealing primarily with crop plants has shown that two considerations are possible for plants to be grown on soils rich in aluminum ions. These can be: A. plants susceptible to aluminum damage (i.e., non-tolerant species); or B. plants resistant to aluminum damage or tolerant of varying concentrations of aluminum in the soil.

It is known that certain plants will not tolerate any concentration of aluminum ions and are killed if grown on soils containing even small quantities of aluminum. Seedlings grown in soils or solutions containing aluminum ions show characteristic effects proved attributable to the concentration of aluminum. Slow growth and contortion of the shoot system comprise the obvious symptoms, but an examination of the plants shows root damage due to the "browning" of the roots or root hairs (Hoffert, G.N. & Carr, R.H. Accumulations of iron and aluminum compounds in some plants and its probable relation to root rot. Jour. Agr. Res. **23**: 801. 1923). Continued deterioration of the root system results in starvation and eventual death of the plants. Previously much of this damage was attributed to the high acidity of the soil.

Information in this category is best known concerning the cultivated and crop plants of the temperate regions rather than the natural vegetation of the tropics where aluminum ore is mined. Gilbert and Pember (Tolerance of certain weeds and grasses to toxic aluminum, Soil Sci. **39**: 425. 1935) reported that aluminum in the soil served to regulate competition between certain weeds and grasses. They concluded that grass seeds and seedlings were less affected by aluminum than dicotyledonous plants and so pasture areas under their observation developed pure stands of grasses, weed-free. (See also Shorland, F.B. The estimation of aluminum in pastures with special reference to soil contamination. Proc. Roy. Soc. N. Zeal. **64:** 35. 1934).

We observed the growth of pastures on areas of known bauxite concentration and the invasion and replanting of mined-out bauxite areas for these plant reactions. Although we are dealing with different genera and species, the results do not support the observations of Gilbert and Pember and of Shorland that aluminum itself in greater concentration limits the selection of species which invade or which could be planted.

It appears to be possible to establish three categories for plants which will grow on aluminum-rich soils. These are: 1. Plants requiring aluminum ions in their metabolism; 2. Plants known as "aluminum accumulators" which concentrate aluminum ions in plant tissues with visible but nonlethal effects; and 3. Plants which are tolerant of aluminum but collect little or only small percentages of aluminum in their tissues.

The role of aluminum as an essential element for plant growth has been investigated for a few areas and a few crop plants. Of particular interest is the fact that members of the Ericaceae, Moraceae and a great many ferns and Lycopodiaceae are considered now to require aluminum for proper development (Shorland, L.C. and Sommers, A.L. Studies concerning the essential nature of aluminum and silicon for plant growth. Univ. Calif. Pub. Agr. Sci. **5** (2): 57. 1926).

*Vaccinium* and *Rhododendron,* according to these reports, will not grow on control solution culture unless aluminum is added to the solution. Field work on the distribution of these two genera in Java supports the idea that aluminum is present where these plants occur and is absent where the species are absent (von Faber, F.C. Die Kraterpflanzen Javas in physiologisch-ökologisches Beziehung. Arb. Treub-Lab., Weltevreden 1. 1927). The distribution of *Vaccinium* species in the Antilles does not seem to follow the pattern described for the Far East. *Vaccinium* species do not occur on the deep bauxite soils in Jamaica but are montane plants, while *Rhododendron* is not native to the Antilles but species are cultivated at higher altitudes where temperature is more a factor than the absence of aluminum in the soil.

Several species of *Ficus* also require aluminum for normal development, according to the work of von Faber (l.c.). Many species of *Ficus* are present in Jamaica and the other islands of the Antilles, but occur apparently without special relationship to the concentration of aluminum ions. They are, however, a conspicuous feature of bauxitic pastures in Jamaica and clearly thrive in this environment.

The most detailed work on plants requiring aluminum has been done on ferns and club-mosses. Yoshii (Yoshii, Y. Aluminum requirements of solfatara plants. Bot. Mag. Tokyo **51**: 262. 1939) found that ferns in the Asiatic area grew most luxuriantly on soils rich in aluminum and that species of *Alsophila*, "*Aspidium*" and *Polypodium* failed to develop normally in the absence of aluminum.

The specific role of aluminum as an essential element is not completely understood. It appears to be associated with maturation, particularly of the fruiting portions of the plant and the setting of seed. Thus corn plants grown on aluminum-rich soils or solutions showed earlier flowering, earlier fruiting and heavier fruit production when compared with control plants (Sommers, l.c.). It is also suggested by literature of the field as reviewed by Hutchinson (Hutchinson, G.E. The Biogeochemistry of aluminum and of certain related elements. Quart. Rev. Biol. **18**: 1, 128, 242, 331. 1943) that aluminum may play a role in the uptake of water by plants. This factor alone may account for the heavier fruit production.

Aluminum may also have a catalytic effect on plant growth as shown in the case of citrus crops. *Citrus*, normally susceptible to damage by copper, is more highly resistant to copper injury when grown on soils rich in aluminum.

More attention has been paid to the ability of certain plants to accumulate aluminum ions as compounds, e.g., aluminum succinate within the tissues of the plants (Smith, H.G. Proc. Roy. Soc. N. S. W. **37**: 107–20. 1903). Such plants are called accumulators and are considered such when the concentration of aluminum ions equals or surpasses 0.01% of the dry weight of the plant. Accumulations as high as 8.5% have been reported in species of *Carpinus*.

The most comprehensive survey of the plant kingdom to determine the frequency of aluminum-accumulating plants in all groups has been completed and reported by Chenery in a series of papers (Chenery, E.W. Aluminum in the plant world. Kew Bull. **1948**: 173; **1949**: 433, 466). The original impetus for such a survey came when it was determined that the historic use of certain plants as mordants for dye work was due to the concentration of aluminum in the tissues. Further study of these mordant plants showed visible characteristics applicable to other aluminum-accumulating plants. In addition to the mordant properties, the presence of a characteristic yellowish green color in the leaves, the presence of pH sensitive anthocyanin pigments which respond to concentrations of aluminum by changing color (as in *Hydrangea*) and the presence of a characteristic bright blue-colored fruit, would indicate an accumulator species.

In his survey Chenery used a test reagent of ammonium aurine tricarboxylate in ammonium acetate, gum acacia and hydrochloric acid. Small fragments of leaf material when boiled in this solution caused a change in the orange reagent to scarlet, crimson or to opaque crimson, depending on the concentration of aluminum in the leaf tissue. It has been shown by other workers that the concentrations of aluminum within the plant are greatest in the roots, becoming less in the stem and leaves. A few plants accumulated aluminum in the roots and failed to transport the ions beyond the root system. L. J. Webb (Aluminum Accumulation in the Australian-New Guinea Flora, Austral. Jour. Bot. 2 (2): 176–196. 1954) has recently reported that "variation in results occurred when samples of the same species were tested from different localities, or when different parts of the tree were tested." In various species Webb reported positive accumulator reactions from one locality when negative from another, or a positive reaction from the bark but negative from the leaf. In *Quintinia sieberi* plants which establish themselves as epiphytes, reactions were negative in young plants, but older ones exhibited a positive test. A second species lacking the epiphytic habit was positive in reaction. Webb concluded that "these variations suggest that aluminum accumulation is not always obligatory among individuals of some species."

The results of Chenery's extensive survey and Webb's comprehensive coverage of a local flora must be considered as being on the conservative side as much of the work was done with dried and herbarium materials, involving only fragments of single plants.

In neither Chenery's nor Webb's work is any evidence given of the presence of aluminum in the soil where these plants were growing. We regret that we have not had the opportunity of applying Chenery's techniques to a survey of the plants growing on bauxite areas of known concentration in Jamaica. Such tests would demonstrate either accumulator or tolerant species.

Webb has listed the families which are known to contain species which accumulate aluminum based on the reports of his own research and that of Hutchinson and Chenery. These are Monimiaceae, Lauraceae, Violaceae, Polygalaceae, Vochysiaceae, Crypteroniaceae, Geissolomaceae, Proteaceae, Theaceae, Myrtaceae, Melastomaceae, Rhizophoraceae, Scytopetalaceae, Euphorbiaceae, Cunoniaceae, Escalloniaceae, Hydrangeaceae, Celastraceae, Icacinaceae, Octoknemataceae, Juglandaceae, Diapensiaceae, Symplocaceae, Diclidantheraceae, Loganiaceae, Apocynaceae, Rubiaceae, Gentianaceae and Lentibulariaceae. Webb considers the data compiled and discusses it along biochemical ecological and taxonomic lines. He suggests as cited in his summary that "A high aluminum content of the organs of accumulating plants appears to be associated with normal metabolism." Further, that "obligate accumulators are confined to leached acid soils from a variety of parent materials, in comparatively high-rainfall areas."

Few of the families which contain accumulator species occur in Jamaica and fewer still on bauxite soils. Chenery points out that the greatest *number* of accumulator species have been found in the Rubiaceae and the Melastomaceae, both families represented in Jamaica, and that the greatest *percentage* of accumulator species belong to the Diapensiaceae and the Symplocaceae. In the latter two families all species tested proved to be accumulators, and for the Symplocaceae Webb found eight species as accumulators of the eight species tested. *Symplocos* occurs in the West Indies and three species have been reported from Jamaica but are not associated with bauxite soils. Such genera containing known accumulating species as *Morinda*, *Oldenlandia*, *Lasianthus*, *Psychotria*, *Miconia*, *Ternstroemia*, *Cyathea*, *Dicranopteris* (*Gleichenia*) and *Lycopodium*, do occur in Jamaica. A few of these genera have been found on bauxite soils but in no case are they limited to bauxite soils. They are, in fact, much more abundant elsewhere, indicating that aluminum in bauxitic concentrations is not necessary for their growth, and that other factors control their distribution in Jamaica. No species of these accumulator genera are restricted to bauxite soils. Certainly the observations of Chenery and Webb that acid soils and high rainfall are required for high accumulator species cannot with ease be applied to the composition and distribution of the vegetation found on bauxite soils in Jamaica.

Webb uses the data regarding accumulator species for practical taxonomic considerations. He reports that the "recorded accumulators are mainly restricted to what are usually regarded as the more primitive groups in dicotyledons and filicales, suggesting that accumulation is a physiological relic in these groups." He points out that "with the exception of the Rubiales, all the well-developed accumulating orders are confined to the Archichlamydeae or the primitive sections of Metachlamydeae. Accumulation is erratically developed in *Rubiales* and only slightly in other Metachlamydeae." If it can be assumed that aluminum accumulation is associated with normal metabolism and therefore characteristic of those species, then until further tests are made, the vegetation which occurs on bauxite soils in Jamaica must be considered as species which are neither accumulators nor non-tolerant of aluminum concentrations. Instead, it appears that the bauxite flora of Jamaica consists of plants which are unaffected by aluminum and tolerant of its presence.

Webb also suggests that accumulation of aluminum seems to be a useful character to supplement other data in the clarification of some taxonomic problems. He cites examples of *Helicia* and *Finschia* where the proper affinities of the species are suggested by the accumulation of aluminum. Manske and Marion (Manske, R.H.F. & Marion, L. The alkaloids of Lycopodium species. Canad. Jour. Res. B. **20**: 87, 153. 1942; **21**: 92. 1943; **22**: 1. 1944) found that in *Lycopodium*, where the color of the plant is often used as a supplementary character for dividing the genus, the color was a direct indication of the percentage of aluminum in the tissues.

We have looked in vain for an application of Chenery's suggestion of blue fruit, yellow-green color to the foliage and pH-sensitive anthocyanin pigments in the vegetation on the bauxite soils. Such plants occur in Jamaica, but without correlation to bauxite. As we have indicated, in the course of our work to the present we have been unable to find undisturbed forests or savannah vegetation on the deposits of bauxite of known concentrations. Explorations by the bauxite companies continue in more remote parts of the island, such as the John Crow Mountains and the Cockpit country where future expansion of the mining operation will take place. In such areas we still hope to encounter a vegetation which will demonstrate the existence of endemic species related to bauxite soils or counter effectively the slight evidence on hand from the deposits in the Dominican Republic and Haiti. To the present we have found no species characteristic of bauxite soils, nor have we demonstrated that the vegetation of adjacent areas currently not found on the bauxite deposits will not grow on the bauxite soils. To the contrary, the invasion of plants from adjacent areas on barren, mined-out pits and the plantations established in these pits indicate that factors other than the concentration of aluminum will control the success or failure of these species on bauxite.

## MINING TECHNIQUES IN JAMAICA REGARDING BAUXITE ORE

Strip-mining techniques for the extraction of bauxite ore in Jamaica are relatively simple in contrast to those used in areas of greater amounts of overburden. The deposits in Jamaica encountered to the present are all superficial, the bauxite having been deposited in pits on a hard limestone base. The nature of these deposits is well described and illustrated by Zans (l.c. 318, plates III, IV and VI), who reports that bauxite deposits are "confined either to circular or oval declines (cockpits) and large elongated 'glades' (bowl or catchment deposits), or to larger, uneven depressions in limestone plateaux blanketed by undulating sheets or lenses of bauxite. Smaller deposits occur in pockets, pipes, and irregular solution cavities on the hillsides of the honeycombed limestone and also filling the fissures and brecciation zones." "All the deposits are surface accumulations, covered only by a thin layer of soil and sparse vegetation." "The deepest pocket drilled in Jamaica is 114 feet deep in a deposit near Williamsfield in the parish of Manchester. Deposits less than five feet in thickness are not considered workable, and the average minable thickness is of the order of ten to thirty feet. The tonnage of the individual commercial ore-bodies varies from a few thousand to several million tons."

In opening the deposits for mining the top soil ("overburden") is removed by bulldozer or dragline scraper and set aside for replacement once mining operations are completed (PLATE VI, FIG. 2.) The removal of the overburden is in part a practical operation and in part a consideration for the future reclamation of the mined-out pit. The overburden contains remnants of the plant life, the root systems and the accumulation of organic material, but consists of the same chemical, i.e., aluminum composition as the lower deposits. Processing of the overburden would require ashing of the organic material. Removing and stockpiling the overburden avoids the necessity for this complicated operation.

With the overburden set aside for future use, the ore is removed by mechanical excavators, power shovels, drag lines or scrapers (PLATE I, FIG. 2 and PLATE VI, FIG. 2.) The ore is then hauled to transportation centers by bottom- and rear-dump trucks. Equipment used and methods of transportation vary with the companies; however, both Kaiser and Reynolds dry the ore, removing eighty to eighty-six percent of the moisture contained. The dried ore is then exported for further processing to alumina and metallic aluminum.

The nature of the depression that remains following removal of the bauxite ore varies with the size of the ore body and with the contour of the hard limestone base. Minable deposits average ten to thirty feet in depth, but a few located in small limestone "cockpits" were deeper, the resulting depressions being steep-sided. The larger the ore body, the less precipitous were the borders of the depression and the easier could be the early steps of pit reclamation. In general, the practice of the companies appears to be to alter steep-sided depressions where possible by blasting or by using tractors to ease material into the hole. Contours of the larger depressions are smoothed with tractors and bulldozers. (PLATE V, FIG. 2 and PLATE VII, FIG. 1.) Overhangs are removed and dangerous slopes fenced off. Once the contour has been adjusted, the overburden is replaced and leveled. Distribution of the overburden is made as uniform as possible and the overburden is contoured with the greatest possible agricultural utilization in mind. The soil surface is then processed, generally using sheepsfoot rollers but occasionally by discing, harrowing or ploughing. Contours are established and attempts at erosion checks are made. (PLATE II, FIG. 2 and PLATE VII, FIG. 1.) The problems of re-establishing vegetation on these naked mined-out pits are evident. Soil samples from the bottom of several pits have been analyzed and show an organic content of 0.10% to 0.15% and a nitrogen count from 0.00% to 0.033%. The pH of these soils varied from 5.9 to 6.1. Potassium counts averaged 0.7% and phosphorous 0.41%. Even with the replacement of the overburden, the organic content remained very low. Without the proper surface preparation the soil is very compact.

## SUCCESSION ON THE EXPOSED MINED-OUT PITS

We have been fortunate in having the cooperation of the managers and the agricultural specialists of both the Reynolds Jamaica Mines and the Kaiser Bauxite Company in the course of our investigations. At our suggestion and with the approval of the Commissioner of Mines, control areas have been established in the mine areas. Mined-out pits have been allowed to stand fallow to permit our observations concerning the natural invasion and succession in mined-out bauxite pits. (PLATE II, FIG. 1).

A complete list of the plants which have appeared as invaders of the mined-out pits appears as a tabulation in the second part of this paper. Within six months from the cessation of mining operations in the control pit at the Reynolds Mines sixty-one species of plants were recorded as established within the pit. A definite zonation was evident with vines, primarily *Cissus sicyoides*, *Mikania micrantha*, *Ipomoea cathartica* and *I. tiliacea* on the slopes and the abundance of herbaceous and woody species in the silted-in center depression. The greater number of invaders appeared on the area where the overburden had been replaced, indicating both the comparatively greater fertility of this soil and the possible presence of weed seeds in the overburden. Additional species which have not been seen in the control pit were found in other pits which received special plantings. It was of interest to note that several species of plants not recorded elsewhere in the area appeared in the mined-out pits. These were *Aster exilis, Lactuca jamaicensis, Crepis japonica*, all herbs, and *Ochroma pyramidale*. Woody plants which were among the early invaders were *Ficus suffocans, Bocconia frutescens, Zanthoxylum martinicense, Cordia globosa, Petitia domingensis* and several species of *Solanum*. *Zanthoxylum martinicense* and *Petitia domingensis* were given special significance as the woods of both species are used for light construction work on the island. During the first year of observation, changes were recorded in the relative composition and the size of the plants. Many species disappeared after one seed generation, but plants known elsewhere as persistent pan-Caribbean weeds remained and often increased in number. Species of *Sida, Solanum, Stachytarpheta, Eupatorium, Lantana, Borreria* and *Cassia* flourished. *Ambrosia* became locally abundant. The vines, especially *Cissus sicyoides* and *Ipomoea cathartica*, fruited heavily and spread rapidly for most of three years, forming a tangle over the ground which impeded travel but seemed to have little effect on the erosion rate of the area. Natural decline of these two species has already set in as other plants have appeared on the slopes of the control pit.

The growth of *Petitia domingensis*, a useful timber tree, has been very slow. *Zanthoxylum martinicense*, however, grew rapidly and has continued that rate. (PLATE III, FIG. 1.) Additional specimens of this species have been recorded since the original observations, and several of these plants increased in height by nine feet between two of our visits, nine months apart. *Ochroma pyramidale*, which was not present in our original observations, appeared subsequently and now towers over the vegetation in the control pit (PLATE III, FIG. 2). Specimens of *Terminalia latifolia* also appeared in the course of our observations and have grown prolifically since. Ferns, particularly *Pteris longifolia*, have appeared in quantity but grasses are scarce, the most abundant plants being *Stenotaphrum secundatum* and *Andropogon glomeratus*. *Stenotaphrum*, like *Cissus* and *Ipomoea*, appears to dominate areas by the long, sprawling habit developed, but these plants have not rooted naturally along the runners and hence are of slight value in retaining the soil.

No attempts at following succession were made on pits which had been planted, since cultivation practices in these areas altered the invading vegetation. One of the goals of the succession study on a controlled pit was to locate if possible a naturally established, ground-covering plant which would reduce erosion. Three plants which were prominent in pits other than our control pit appear to serve this purpose. They are *Mimosa pudica*, a legume capable of enriching the soil, *Borreria laevis* and *Wedelia fragilis*. Both *Mimosa pudica* and *Borreria laevis* seem well suited for the purpose, being low, prostrate plants which seed abundantly and cover well. The latter is eaten by cattle and could be considered low forage.

However, it has been suspected of producing toxic effects and should be encouraged only with this caution in mind.

As might be suspected in the drier area of the Kaiser operations in St. Elizabeth, the rate of invasion was slower than at Reynolds and the number of species at a given time was fewer. Thus, in six months following the cessation of mining operations, a control area on the Kaiser property had only forty-one species of plants. These were fewer in individual representatives and much more scattered in distribution. Subsequent changes at Kaiser have not shown the same loss of species and in our last visit all the species encountered in previous visits were still to be found. Additional invaders have been few. Grasses such as *Setaria*, *Andropogon*, *Digitaria*, *Cenchrus* and *Stenotaphrum* are more numerous and specimens of *Haematoxylon* and *Lantana* appear to be the most conspicuous elements. *Haematoxylon* is probably the most abundant plant in the valley near the mining operations and with its samara-like fruits is obviously distributed widely. The logwood, therefore, must be considered in any attempts to maintain pastures or woody plantings in the mined-out pits. No plants of potential economic value have appeared spontaneously in the Kaiser pits.

The relative fertility of the overburden when stockpiled adjacent to the mining operations has drawn the attention of visitors to the mine area. It must be pointed out that the overburden contains not only the organic matter and the roots, but the fruits and seeds of the area. Thus the rapid covering of relatively luxuriant vegetation on the stockpile of overburden is mostly indicative of the presence of plant life and propagating material in the soil. At the Reynolds Mine area we have been able to watch the development on stockpiles of overburden of twenty-three species of plants which in four years of observation have not appeared spontaneously in the mined-out pits. These plants include five pasture grasses as well as the following potentially valuable economic plants: *Musa sapientum*, *Cecropia palmata*, *Ricinus communis*, *Hibiscus elatus*, *Ceiba pentandra* and *Pimenta dioica*. In the Kaiser area none of the plants recorded from stockpiles of overburden is different from those appearing as natural invaders of the mined-out pits. Of the natural invaders, only *Haematoxylon campechianum*, the logwood could be considered of any economic value.

## REPLANTING THE MINED-OUT PITS

The majority of mined-out pits on the Kaiser properties have been of such contours to allow development as pasture areas. In these plantings a variety of pasture grasses have been attempted by seed and rhizome propagation. Most have been established as pure stands. Guinea grass (*Panicum maximum*) has proved the most successful and controlled grazing has already been permitted on several of these reclaimed pits. (PLATE VII, FIG. 2.) Pangola grass (*Digitaria decumbens*) is now being tried both for forage and erosion control and looks promising. Para grass (*Panicum purpurascens*) and Wynne grass (*Melinis minutiflora*) have not, to our view, been so successful. In all pasture areas there has been an invasion of weed herbs and woody species and these have necessitated manual labor to maintain the pastures.

The Kaiser Company has also devoted some of its reclaimed pits, generally those of steeper contours less suitable for cattle, to reforestation. In general these have received mixed plantings, although some nearly pure stands have been set out. The seedlings are obtained from the Forestry Department, usually from their nurseries at Spanish Town on the south coast, to supply plants which have been started and grown under comparable conditions of temperature, exposure and rainfall. Forest tree plantings have been primarily of *Swietenia mahogani* (mahogany), *Cassia siamea*, *Hibiscus elatus* (mahoe), *Cedrela odorata* (cedar), *Tectona grandis* (teak) and a very few specimens of *Melia composita*. *Swietenia*, well adapted to the environmental conditions of the area, has done well. Plantings two years old average six feet in height and about an inch in diameter at breast height. Some infestation of tip borers has been experienced. The habit of these plants is normal and little pruning appears necessary. The few specimens of *Melia composita* have shown the most rapid growth rates, with specimens two years old reaching now to over twenty-seven feet. In all cases, these have been planted in the lower portions of the depressions. *Cassia siamea* is little grown as a timber tree in the New World, but is often planted as a source of building poles, fuel and lumber in Asia. When interplanted with *Hibiscus elatus* or *Swietenia* these trees have done well and since they will mature more rapidly, will be cut as a source of fuel and as a means of thinning the plantings. (PLATE IX, FIG. 2.) Some trees of *Cassia siamea*, three years after planting, are now twenty-five feet tall with diameters of eight inches and are in flower.

A few plantings of economic or agricultural crop plants have been attempted without outstanding success. Lime and other citrus plants have not adapted themselves to the area and survivors have tended to branch from the base to produce dense and crowded crowns. The pigeon pea, *Cajanus cajan*, has been grown on the mined-out pits but has not fruited so heavily as control plants on undisturbed soils.

More recent plantings have been on deeper soils in mined-out pits and greater attention has been given to soil preparation. One mined-out pit has been devoted to test plantings of peanuts, cassava, sweet potatoes and a variety of garden vegetables. Commercial fertilizer has been used and the crops appear to flourish vegetatively, although a complete crop cycle has not elapsed. On well-tilled soil the peanuts have flowered and produced small fruits which at the time of our last visit had not matured. A variety of fruit trees including breadfruit and mangoes have also been planted in this area.

The development of plantings of *Hibiscus elatus* from the foresters' viewpoint has been most disappointing in the St. Elizabeth area. Originally our observations indicated a high percentage of loss following transplanting and of the survivors a majority suffered die-back. (PLATE VIII, FIG. 1.) Such a response has been attributed to the toxic effects of aluminum ions in the soil. Our initial reaction was that this significant timber species in

Jamaica was not adaptable to reforestation of mined-out pits. However, in subsequent visits it has been apparent that not all the plants suffering from die-back necessarily died. In fact, a majority of these sprouted from the base and presented a problem of a different nature. Additional observations have shown that if mahoe seedlings are given proper care between digging and replanting, losses can be reduced. Furthermore, while watering of transplanted trees is impractical, planting times can be adjusted to rainy periods and survival percentages thus further increased. Mulching would also be helpful. The problem of managing large plantations of trees which have suffered die-back and have branched from the base is, however, an imposing one. Obviously several trunks cannot be permitted. (PLATE VIII, FIG. 2.) Laborers must be trained in proper pruning practices regarding these plants. In general the mahoe growing in mined-out pits in St. Elizabeth, in contrast to those planted in St. Ann, have not grown in height at the expected rate. Instead the average plant has developed a much more dense crown and has branched freely from the lower region of the trunk. Crown development in width and density has dominated trunk development. Again the question is raised of the economic feasibility of pruning branches for trunk development.

*Hibiscus elatus* as a timber tree has not proved as satisfactory on the mined-out bauxite pits in St. Elizabeth as it has on comparable pits in St. Ann and on other terrain elsewhere in Jamaica. From information so far obtained, the climate of the valley near Gutters is not ideally suited for the growth of the mahoe as a timber tree.

Maintenance problems of young forest plantations in St. Elizabeth seem slight in comparison with those encountered in St. Ann. Most evident is the lack of vines which strangle or contort the saplings and the cleaning of forest plantations in St. Elizabeth can be regarded as a minor expenditure.

In the operational area of Reynolds Jamaica Mines in St. Ann (as in St. Elizabeth) both pasture development and forest planting has been carried out. Only a few of the mined-out pits have been considered of suitable shape for the development of new pastures. In these either guinea grass (*Panicum maximum*) or para grass (*Panicum purpurascens*) have been planted primarily by rhizome propagation. One area is documented in photographs which show the contours of the valley prior to and during mining operations and after reclamation. (PLATE V, FIGS. 1 and 2.) A survey was made of this area before mining operations began to record the quality of the pasture in terms of the plants present. Comparatively, the area which would carry at most one cow for every five acres before mining operations began, will be expected to supply forage for at least one cow for each acre now that the pasture is well established. Reclamation in this area has increased the available pasture, improved its quality and definitely improved the contour of the area by an increase in the level acreage.

More recently, para and guinea grass clumps have been planted in steeper contoured pits along with forest trees. It has been demonstrated that the clumps of grass serve effectively as checks to the erosion which was destroying many of the forest tree plantings. (PLATE II, FIG. 2 and

PLATE IV, FIG. 1.) Pangola grass (*Digitaria decumbens*) is also being tried in the vicinity to rebuild overgrazed pastures and as an erosion control.

In the mined-out pits of steeper contours, where pasture establishment is not possible, forest trees have been planted. The nature of the environment in these areas has been deemed most suitable for mahoe (*Hibiscus elatus*) and fruit trees. *Cassia siamea* and *Swietenia mahogani* have not been tried in the area. It is hoped that future planting plans will include prickly yellow (*Zanthoxylum* spp.), fiddlewood (*Petitia domingensis*), broadleaf (*Terminalia latifolia*) and balsa (*Ochroma pyramidale*), which have proved in the control pits to be adaptable to the area. As these timber trees are valued in local industry, plantations of these will find a ready market when mature.

By contrast with the plantings in St. Elizabeth, the mahoe in the Reynolds Area of St. Ann adopts an upright although slender habit and has, in all cases observed, produced a fine trunk branching at normal, i.e., higher levels. Larger plants now two years old are twenty feet high with trunk diameters of five inches and are in flower. (PLATE IV, FIG. 2). Die-back was originally evident in the early plantings of mahoe and the avocado in the St. Ann area, but such die-back seems more readily controlled by giving greater care to transplanting practices and to the time of planting in relation to the rainy months.

Plantings of avocadoes (*Persea americana*) called "pear" in Jamaica have proved successful on the reclaimed pits. (PLATE II, FIG. 2 and PLATE IV, FIG. 1.) With the selection of the best strains or by budding the trees once the root system is established, an important economic crop can be assured.

In the moist climate of the Reynolds operations, *Pinus caribaea* shows signs of promise as a timber tree. Small experimental plantings two years old show excellent growth to five feet.

The workers of the mines have added materially to the experimental selection of plants for the mined-out bauxite pits through surreptitious planting of a variety of vegetable crops. We have followed the illegitimate gardens with interest and have observed that corn (*Zea mays*), cabbage and beans have done well. Less successful have been plantings of yams (*Dioscorea*), taro or "coco" (*Colocasia*) and cassava (*Manihot*). Pumpkin vines produced an abundant crop.

The problem of erosion control has been a major one in this area of sixty-six-inch rainfall. A test planting was made of kudzu (*Pueraria lobata*), but these plants failed to thrive, though a few have survived. Mulching of the forest trees has been found successful in reducing the loss of these seedlings due to erosion. Mulching materials are scarce in the area and burlap sacks weighted down with rocks proved less successful than sizable tangles of vines surrounding the trees and weighted with logs or rocks. (PLATE II, FIG. 2). Scattered plantings of grass tufts within the forest tree plantings have also helped to reduce erosion. Application of chicken manure or commercial fertilizer has hastened the establishment of the grass. Experience has shown, however, that until a complete ground cover is established, sizable accumulations of silt can be expected in the bottoms of the mined-out pits. If saplings are planted in the bottom areas, silting causes the death of a high percentage of these young trees. Planting practices have been adjusted accordingly in recent operations.

Weed control, especially control of vines, remains a major problem in plantation management in the Reynolds area. Only constant attention in the first few years of growth will prevent the vines from either strangling or contorting the young trees. *Ipomoea cathartica* and *Ipomoea tiliacea* are the major pests, along with several others of lesser importance. Hand labor originally was directed at cutting these vines away from the young trees, but this technique had little lasting effect. More recently, grubbing all the plants from the area at the base of the tree with a broad-bladed hoe has been more effective. Clearing the area of vines has also supplied the mulching material to be applied in newer forest plantings where a ground cover of vegetation has not been established.

These initial years of mining operations in Jamaica have been marked with admirable cooperation between the government of Jamaica, through its various departments, and the mining companies. The strip-mining technique and its implications are new to the islands of the West Indies. Certainly the program of land reclamation following mining operations is new to the tropics of the Western Hemisphere. Much has been learned in the past four years and although not all problems are solved, the direction of cooperation and intent is encouraging. The improvement of existing agricultural lands, the rehabilitation of mined-out pits, the introduction of new capital and additional employment, the added source of local and governmental income and the demonstrations of new techniques along with the exchange of knowledge have been the subject of mutual concern and mutual welfare to the government, the people and the mining companies. Agriculture and forestry have taken steps forward in meeting the problems presented and it is hoped the information gained will be shared in furthering the knowledge and the welfare of the West Indies.

(*To be continued*)

ARNOLD ARBORETUM
and
THE INSTITUTE OF JAMAICA

## EXPLANATION OF PLATES *

PLATE I, FIGURE 1. View of the escarpment and area of mining operations of Reynolds Jamaica Mines near Lydford P. O. in St. Ann Parish. Pasture area in foreground is on a limestone outcrop. The intermediate area represents a deeper body of ore. Areas in view between wooded limestone outcrops have been mined out and replanted. Arrows indicate areas of transects. Lower arrow shows forest of TRANSECT #1 and upper arrow, forest of TRANSECT #2.

* PLATES I–V: Reynolds Jamaica Mines area in St. Ann. PLATES VI–IX: Kaiser Bauxite Company in St. Elizabeth.

PLATE I, FIGURE 2. Mining operations in St. Elizabeth. A cockpit-type depression between two limestone hills containing accumulations of bauxite ore being mined by power shovel.

PLATE II, FIGURE 1. A mined-out ore body now preserved as a control area. Six months after mining operation ceased only herbaceous plants and young shrubs were present. Two and one-half years later, at the time of this picture, shrubs dominate the herbaceous invaders and five species of trees, starting from seed, have grown into conspicuous plants.

PLATE II, FIGURE 2. A mined-out ore body adjacent to control pit. The need for a covering vegetation to control erosion is evident. Young avocado plants are mulched with vines and debris cut from adjacent fields. For a comparison showing the growth one year later, see PLATE IV, FIGURE 1.

PLATE III, FIGURE 1. *Zanthoxylum martinicense* in control pit. This specimen first recorded as a six-inch spontaneous seedling and then as a sapling three feet tall nine months prior to the date of this picture.

PLATE III, FIGURE 2. Woody plants in the control pit representing spontaneous invaders grown from seed. *Ochroma pyramidale, Zanthoxylum martinicense, Cecropia palmata, Terminalia latifolia* and *Petitia domingensis* are all represented in this group. Growth to heights of twelve (*Zanthoxylum*) and fifteen feet (*Ochroma*) occurred in the period of two years' observation.

PLATE IV, FIGURE 1. An avocado tree which bore several fruits two years after being planted as a sapling (see PLATE II, FIGURE 2) on a mined-out bauxite pit. Para grass and wynne grass have been planted on the slopes of this pit and were fertilized with an initial application of chicken manure. The grasses now appear to have become established and are effectively checking the erosion on the slopes.

PLATE IV, FIGURE 2. Mahoe (*Hibiscus elatus*) planted on a mined-out pit. The largest specimens shown were planted as saplings about three feet tall two years previously. The plants died back to six inches in height (see PLATE VIII, FIGURE 1) before the root system became established. The plants were pruned to a single stem and the trees illustrated developed to a height of eighteen feet with trunk diameters of six inches in two years. The smaller trees shown in the picture indicate that growth is slow until a vigorous root development is made. Several trees show trunks covered with herbaceous and semi-woody vines. The ground cover is natural weed vegetation dominated by *Borreria verticillata* and *Wedelia gracilis*, with *Mimosa pudica, Desmodium canum* and *Bidens cynapifolia* also abundant.

PLATE V, FIGURE 1. Pasture area in St. Ann prior to mining. Shrub invasion of one section of this pasture is conspicuous in the foreground.

PLATE V, FIGURE 2. The same area two years later. Bauxite ore has been removed. The pit surfaces were contoured and the overburden replaced. The rehabilitated pit was then planted to para grass and fertilized with chicken manure to establish the grass. The relative productivity of the area has been increased about five times in terms of quality pasture with a slight increase in pasture acreage in this tract.

PLATE VI, FIGURE 1. Area of Kaiser Bauxite Company mining operation in St. Elizabeth parish. Photograph shows the dominance of shrubby vegetation on a pasture area. Two years earlier this pasture had been open and was easily grazed by cattle. Shrubs are *Solanum* spp., *Haematoxylon campechianum* and

*Latana camara*. Two forested limestone outcrops are visible in the background. The area between the forests of broad-leaved species comprises a dense stand of logwood (*Haematoxylon campechianum*) on limestone with recent development of broad-leaved species not evident in the photograph. TRANSECT #8 was made in the forested hill on the right. QUADRAT #6 was made in the overgrown pasture beyond the right-hand side of the picture.

PLATE VI, FIGURE 2. An area near New Buildings in St. Elizabeth being prepared for mining. The overburden has been removed by bulldozers and is piled at the left of the picture. A dragline shovel in the center at the rear is used to remove the ore.

PLATE VII, FIGURE 1. An area comparable to that of PLATE VI, FIGURE 2 following planting of forage grasses. Mining has been completed. The deeper pits have been partially filled and the slopes eased. Contours have been established on the slopes and pangola grass has been planted.

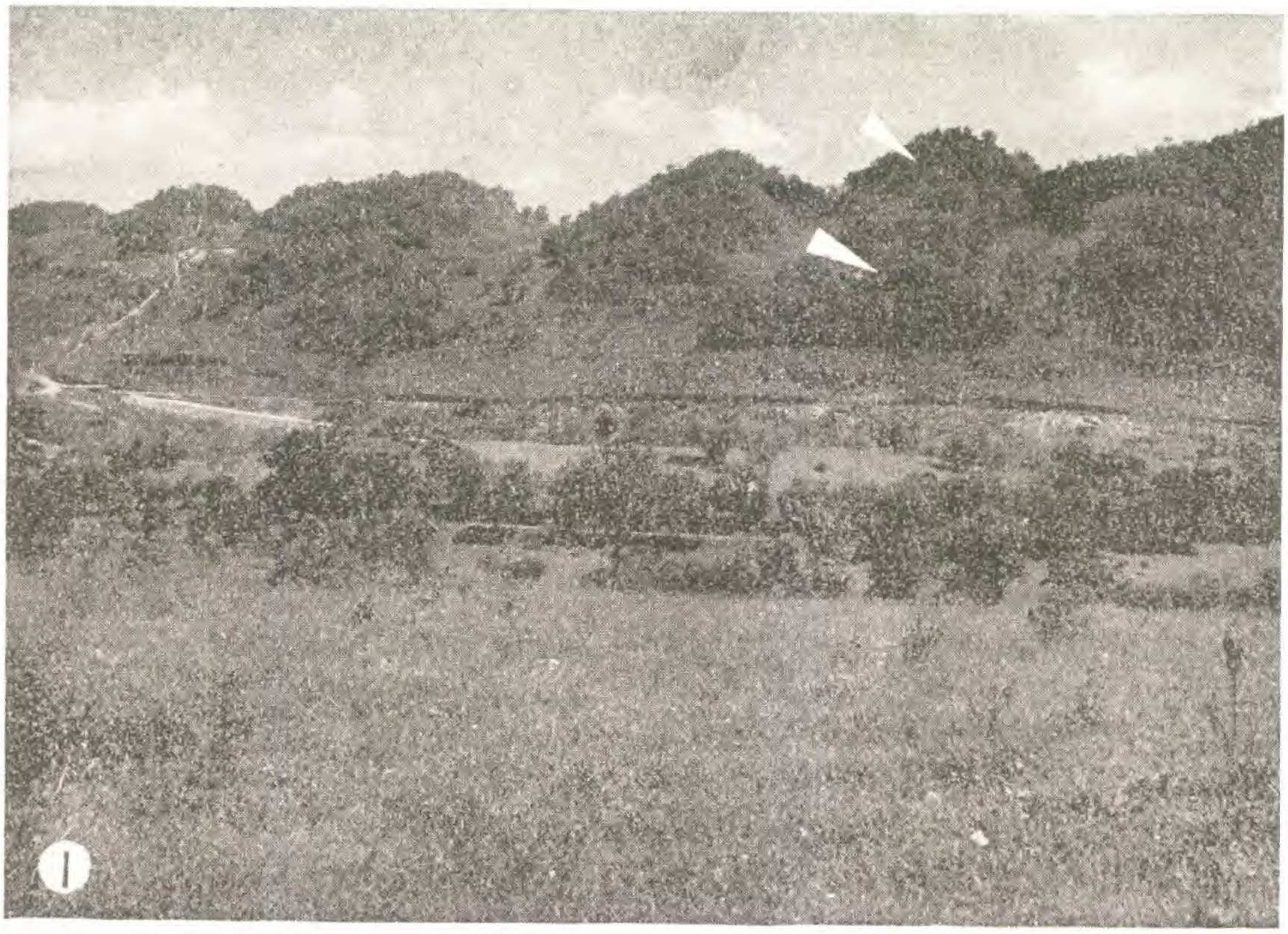
PLATE VII, FIGURE 2. A mined-out pit replanted to guinea grass. This stand is one year old. Commercial fertilizer was used to establish the grass.

PLATE VIII, FIGURE 1. An example of "die-back" in young mahoe plants. A three-foot sapling has died back to six inches and three lateral buds have started to develop into shoots. Die-back has been reduced by better soil preparation and by more careful attention to planting during the rainy periods.

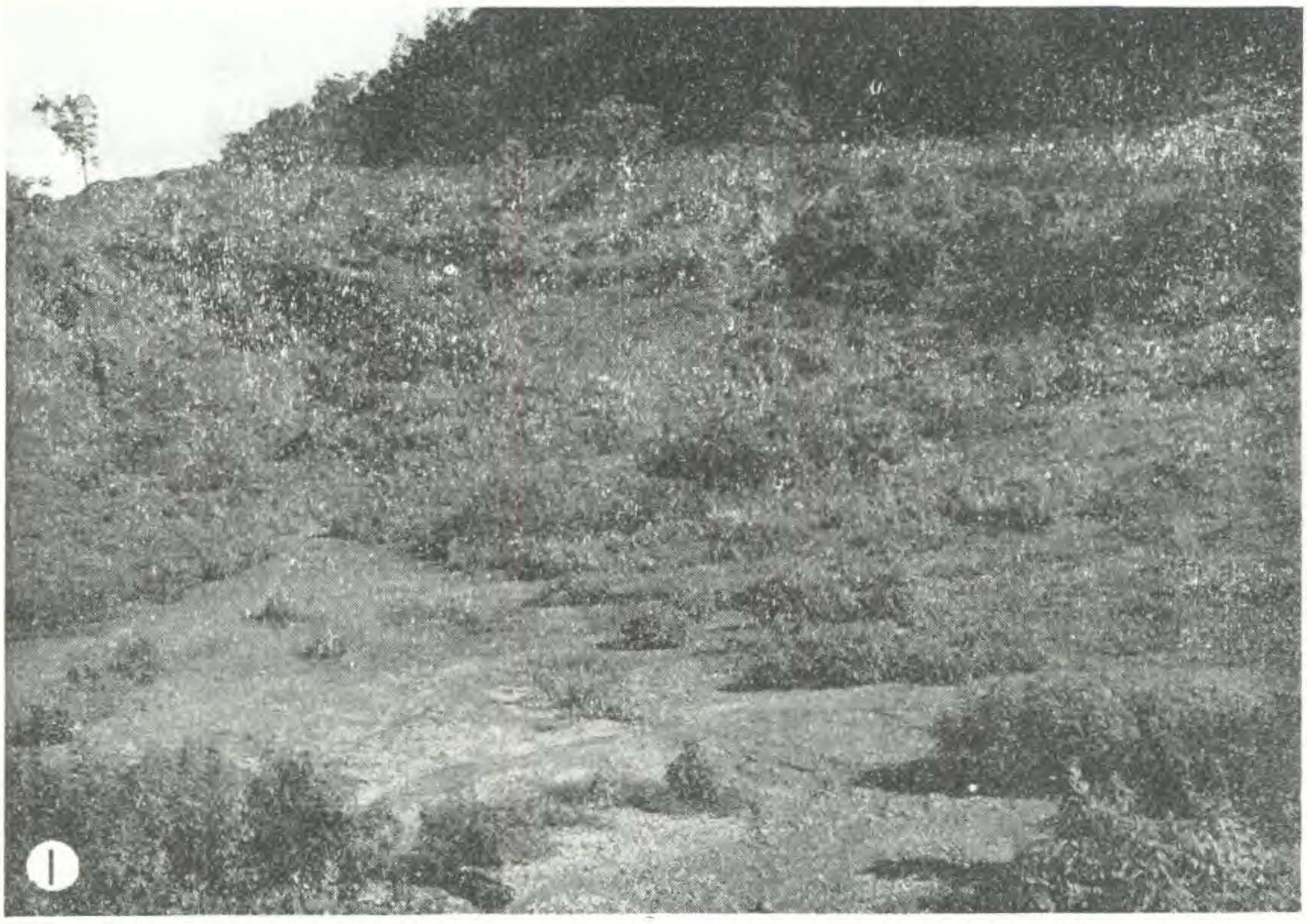
PLATE VIII, FIGURE 2. The type of mahoe plant which develops from saplings having suffered from die-back. Such a tree is of no commercial value. Proper pruning is essential for plants which suffer die-back if a single-trunked, marketable timber tree is to be produced.

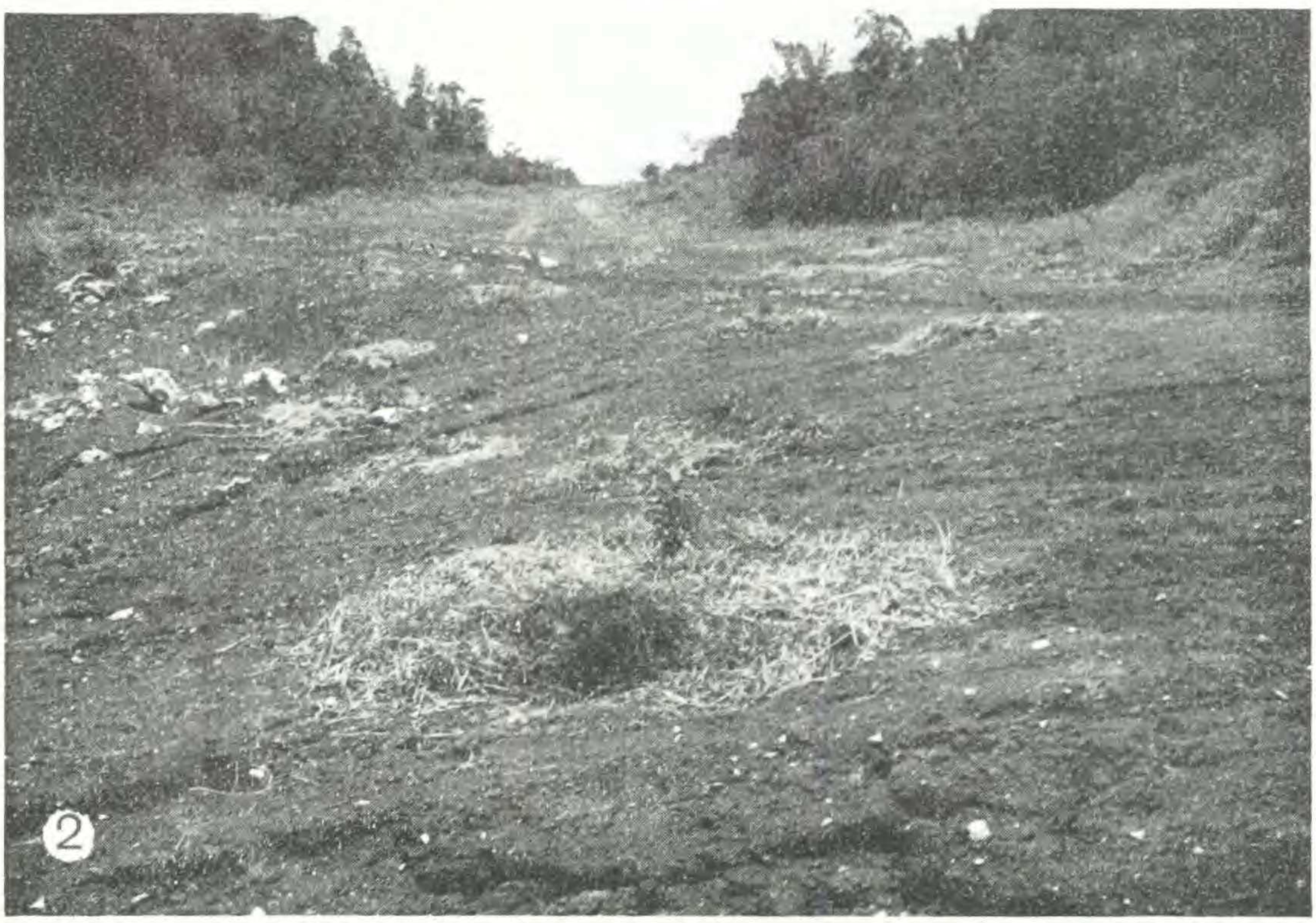
PLATE IX, FIGURE 1. A mature stand of logwood (*Haematoxylon campechianum*) on bauxite soils in St. Elizabeth. The commercial market for logwood has been small in the last decade, but limited supplies can still be sold. Few broad-leaved species are found in logwood forests on bauxite soils in contrast with the dominance of broad-leaved species over logwood on limestone outcrops.

PLATE IX, FIGURE 2. Forest planting on a mined-out pit in St. Elizabeth. The photograph was taken three years after planting saplings in the area. Plants of *Cassia siamea* on either side of Mr. Proctor are twenty feet tall with trunk diameters of five inches at breast height. The mahoe shown at the sides were fifteen feet tall and were in flower. The mahogany trees in this mixed planting were seven feet tall and one is shown at the right side of the picture. Proper pruning practices have been essential in this area where both *Cassia siamea* and *Hibiscus elatus* plants tended to branch freely near the base. The plants illustrated are the best specimens in this rehabilitated pit area and cannot be regarded as average for the area.



HOWARD & PROCTOR, VEGETATION ON BAUXITIC SOILS

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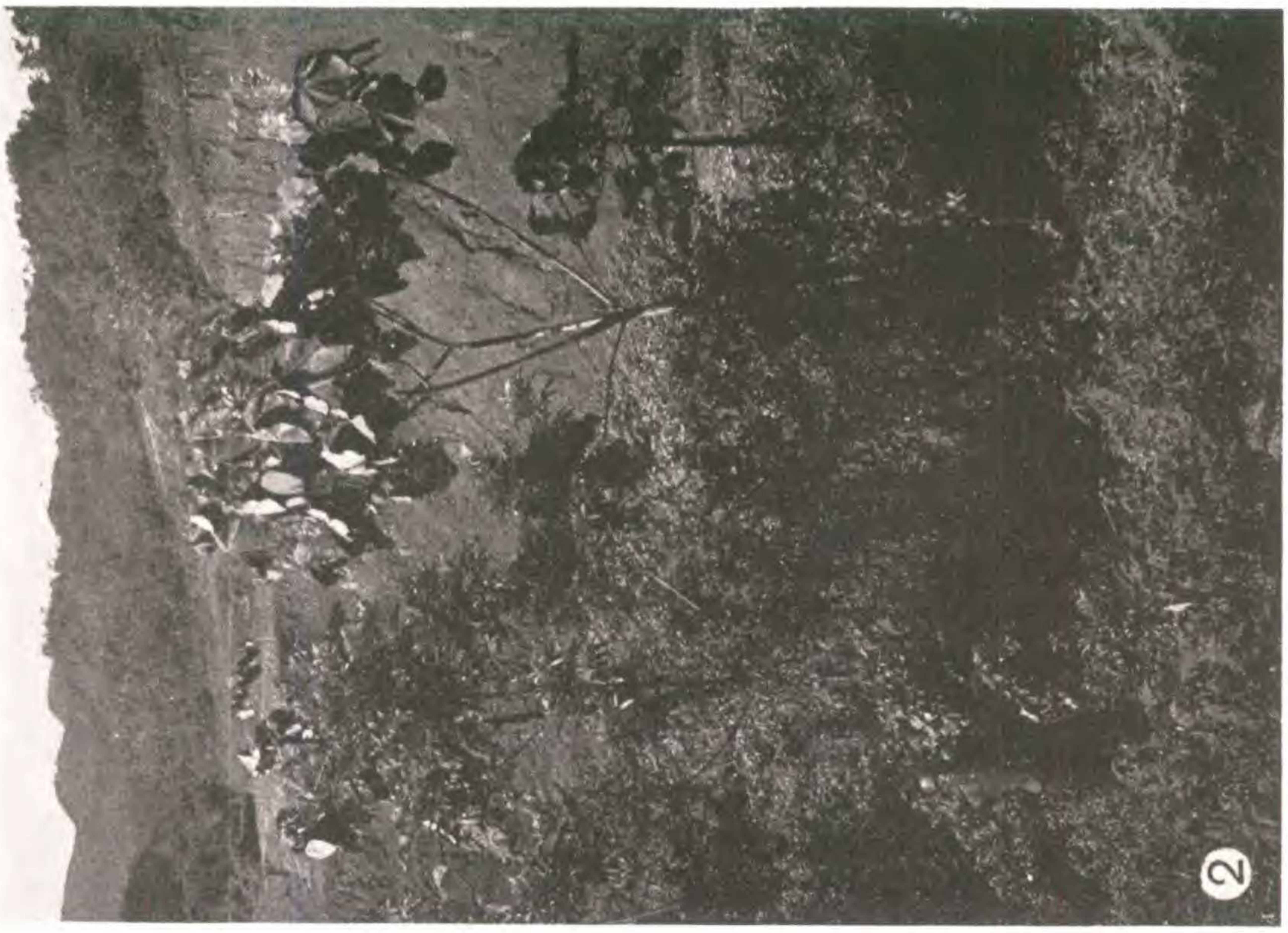

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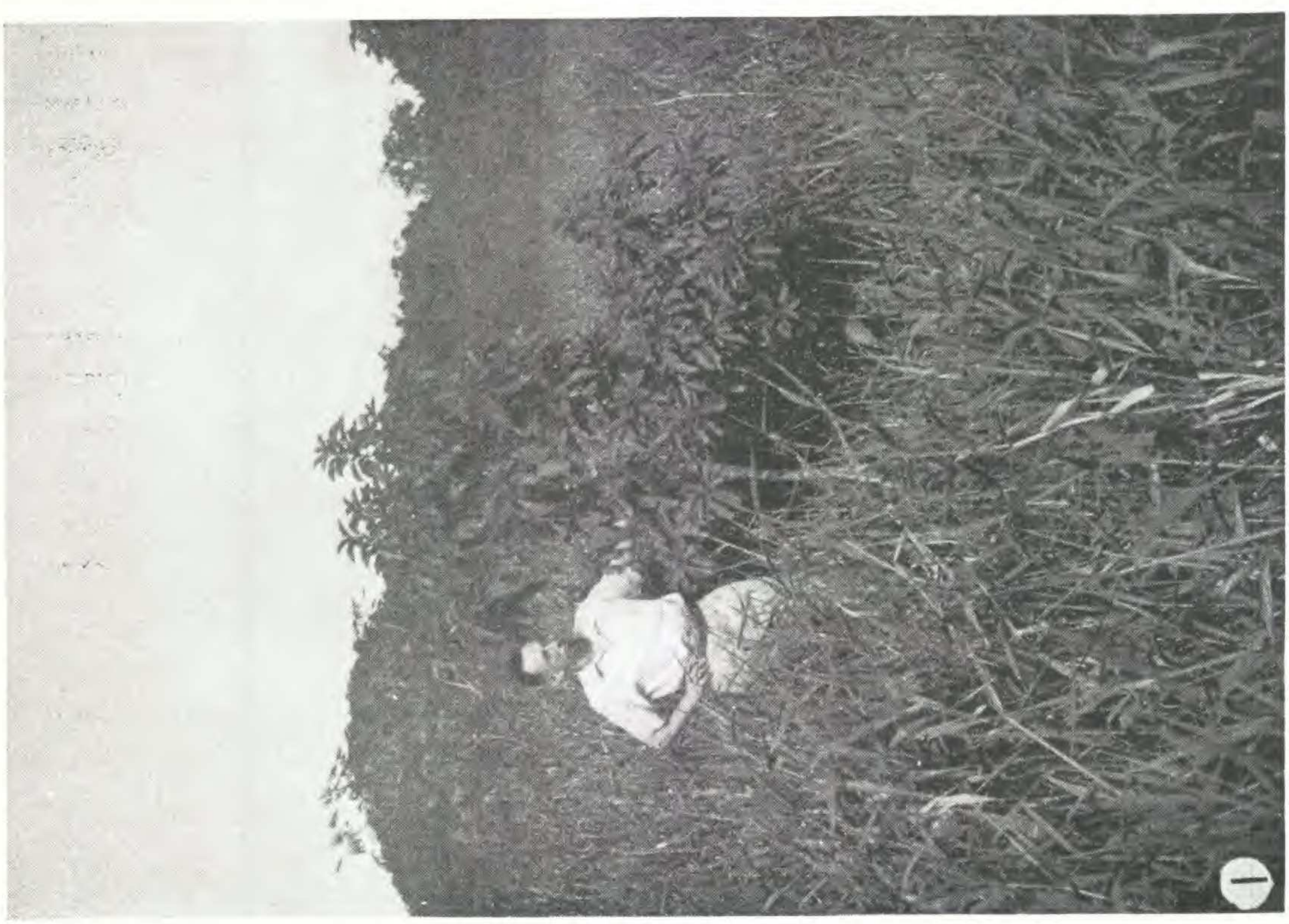
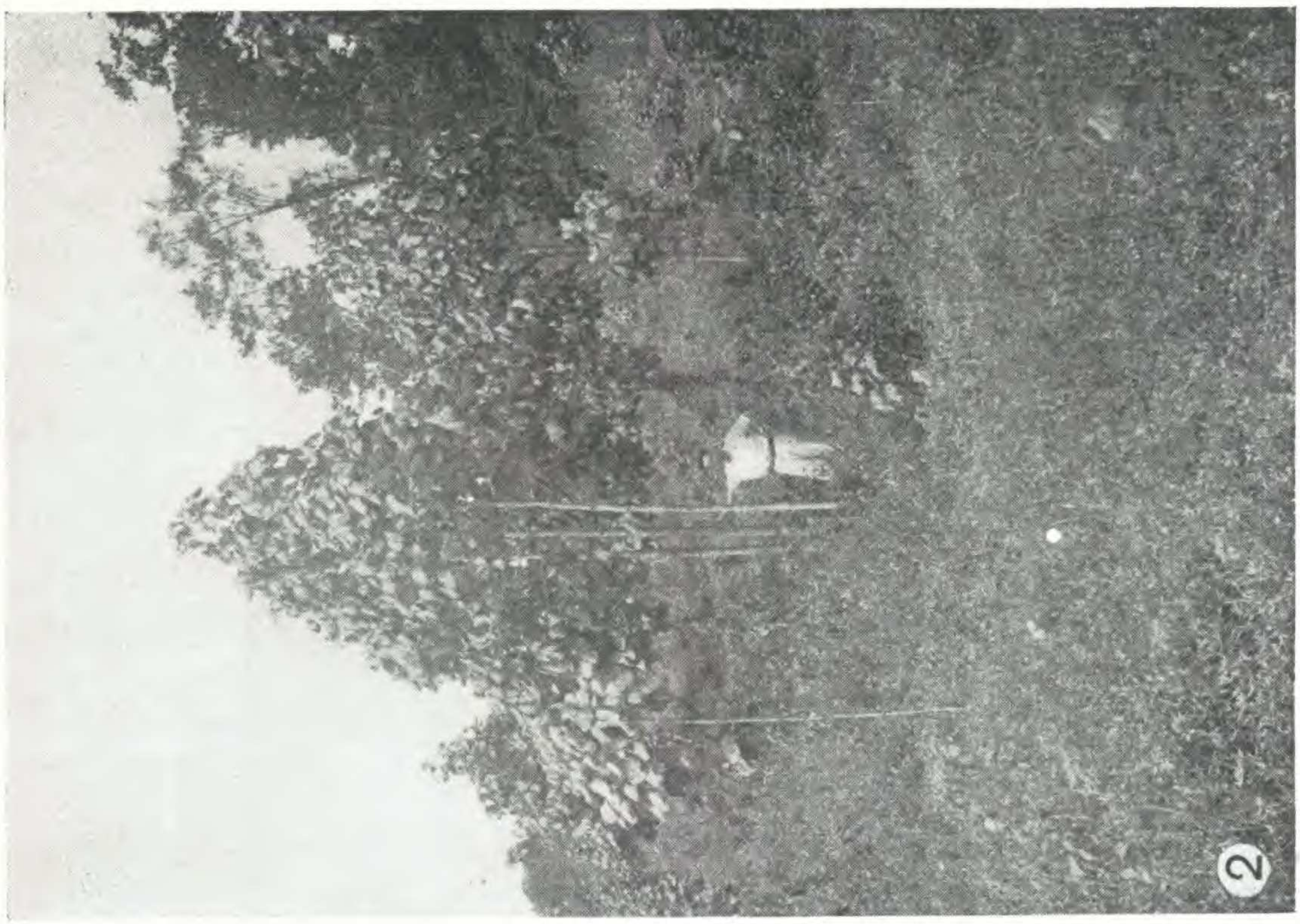
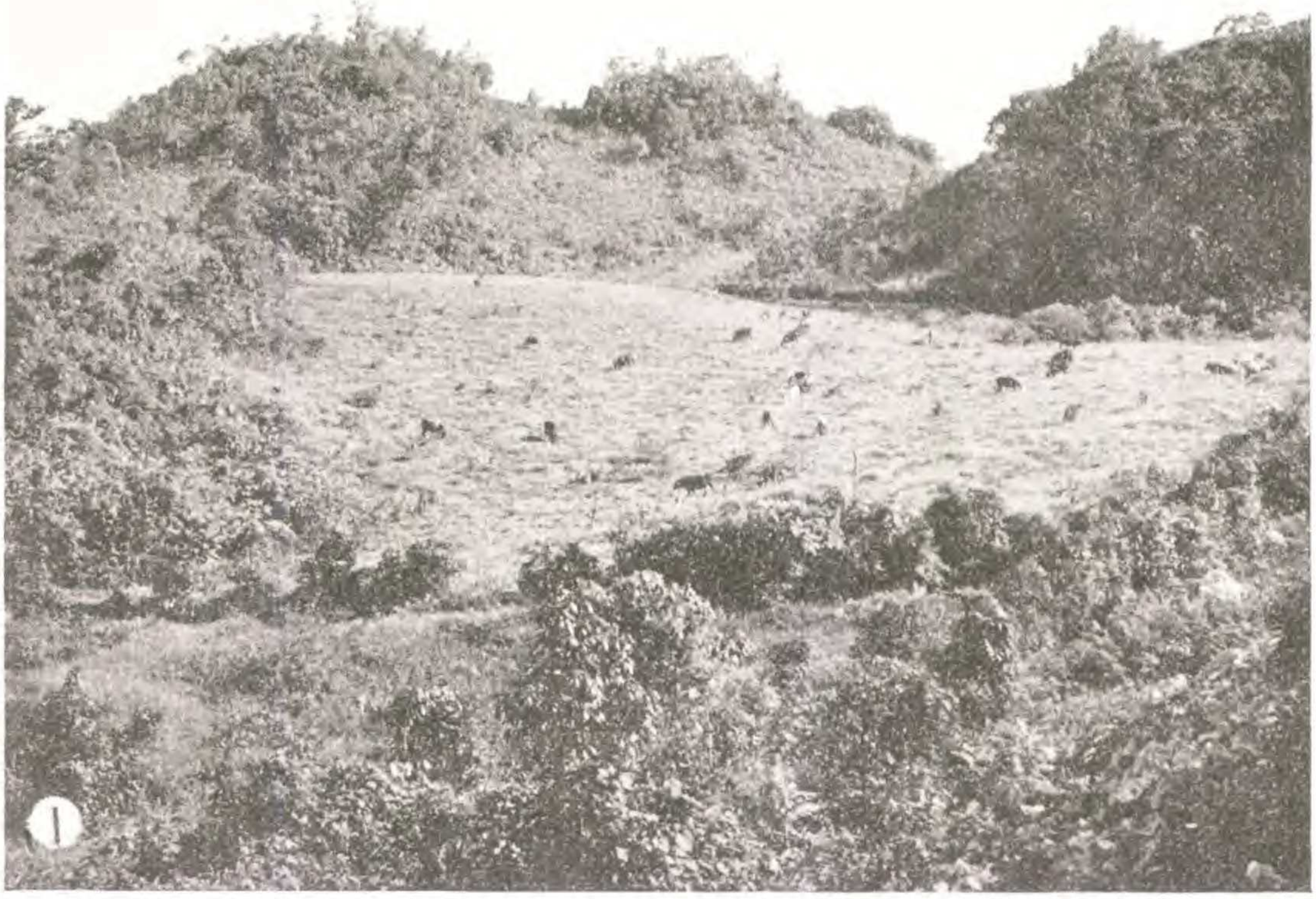
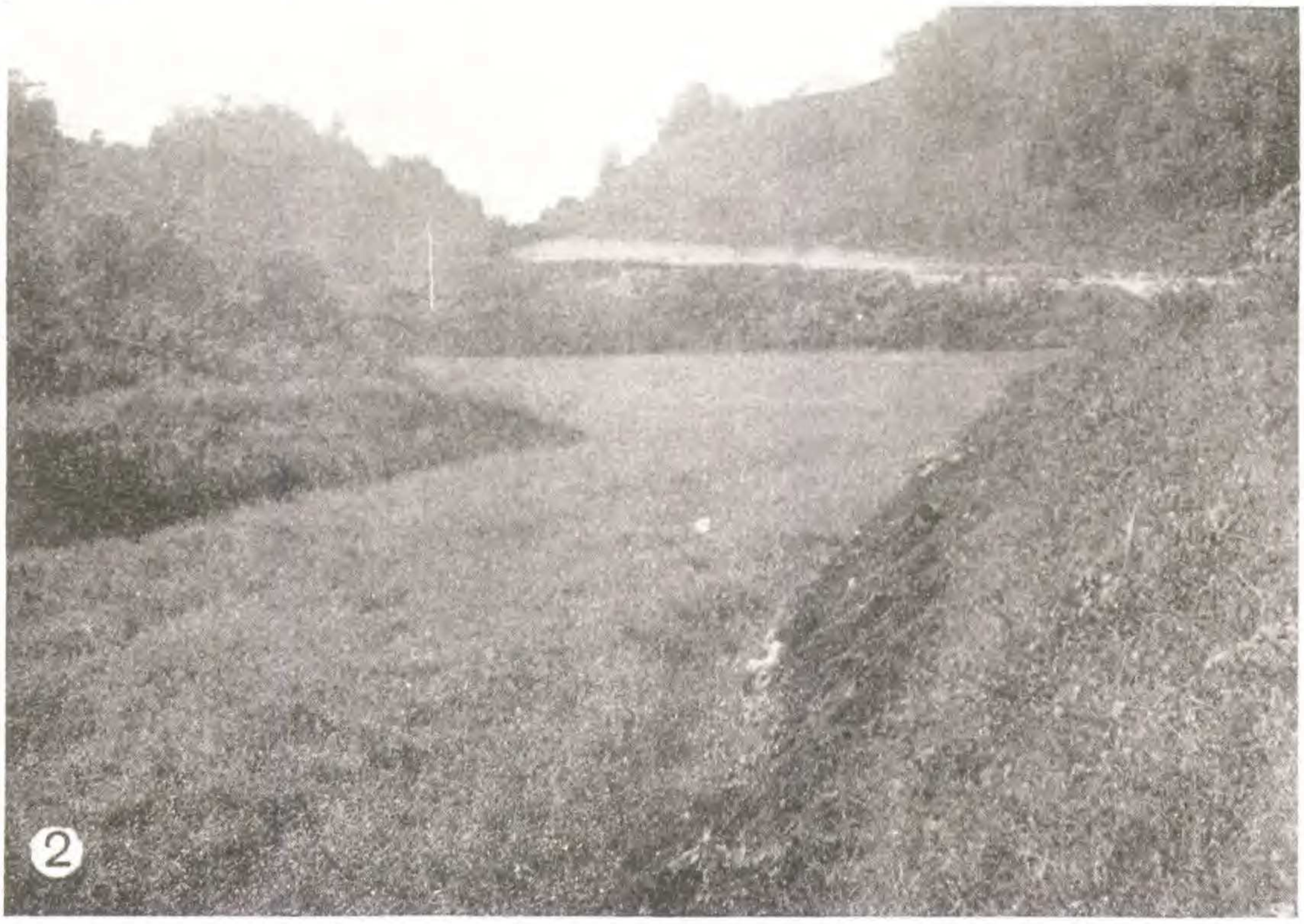



Howard & Proctor, Vegetation on Bauxitic Soils

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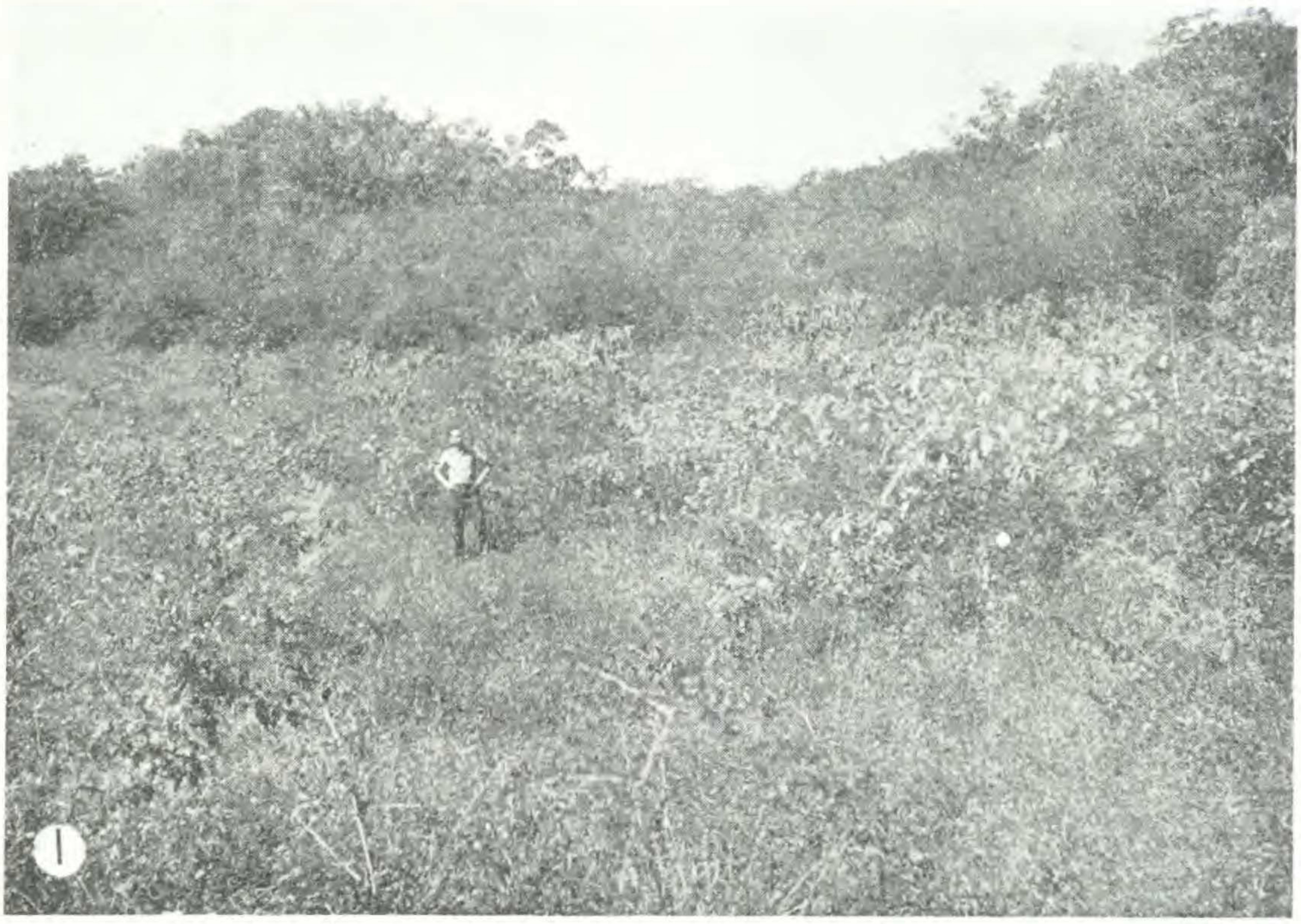
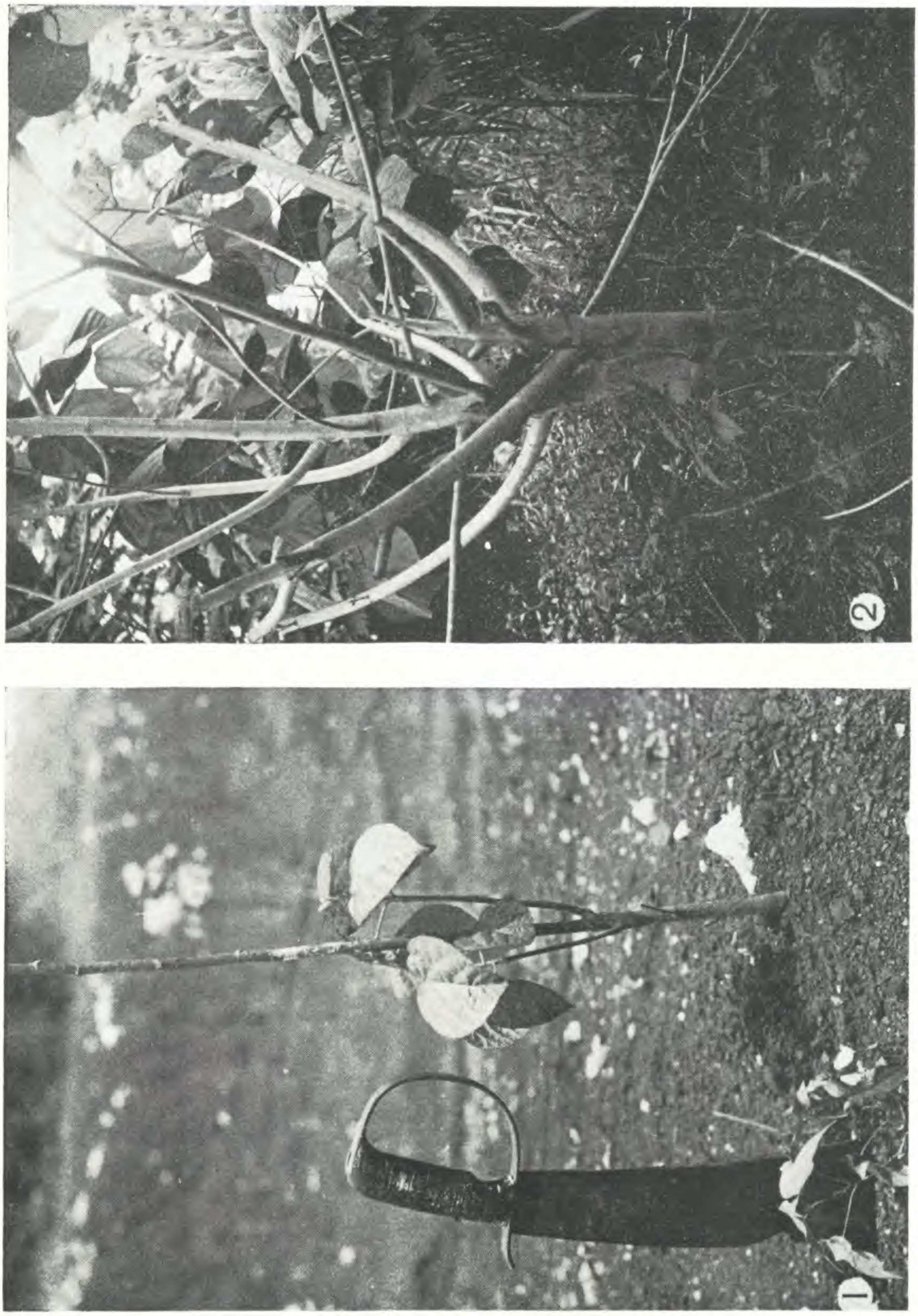




HOWARD & PROCTOR, VEGETATION ON BAUXITIC SOILS



Howard & Proctor, Vegetation on Bauxitic Soils



Howard & Proctor, Vegetation on Bauxitic Soils



HOWARD & PROCTOR, VEGETATION ON BAUXITIC SOILS